Network Centric Warfare Case Study

U.S. V Corps and Third Infantry Division during Operation Iraqi Freedom Combat Operations

Prudens Futuri

NETWORK CENTRIC WARFARE CASE STUDY

U.S. V CORPS AND 3RD INFANTRY DIVISION (MECHANIZED) DURING OPERATION IRAQI FREEDOM COMBAT OPERATIONS (MAR-APR 2003)

Volume II: A View of Command, Control, Communications and Computer Architectures at the Dawn of Network Centric Warfare

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U.S. V Corps and 3RD Infantry Division (Mechanized)
During Operation Iraqi Freedom Combat Operations (Mar-Apr 2003)

Volume II: Command, Control, Communications and Computer Architectures

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The cover image for this volume is a network grid imposed over a combat photo. The photo "Communications Horizon at Dawn: The 123d Signal Battalion, Third Infantry Division during Operation Iraqi Freedom, April 2003" is used by permission of SPC Cory Goodspeed. The network grid is used by permission of www.KurzweilAI.net.

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Foreword

This volume builds upon the results of a study of Network Centric Warfare entitled "Network Centric Warfare Case Study, Volume I: Operations, U.S. V Corps and 3rd Infantry Division (Mechanized) during Operation Iraqi Freedom Combat Operations (March-April 2003)."

During the past decade, the United States Armed Forces have been in the process of transforming from an Industrial Age to an Information Age military. Although this transformation is a long way from being completed, the maneuver phase of Operation Iraqi Freedom demonstrated the emerging power and potential of information-networked forces.

The Army's tactical communications architecture was still strongly grounded in legacy systems of the Cold War as late as 2002. Although the shortcomings of these systems were recognized in the Persian Gulf War of 1991, the architecture had changed little over the ensuing decade. To compensate for the anticipated shortfall in modern battlefield video and data bandwidth demands for Operation Iraqi Freedom, the Signal Corps community of soldiers and civilians rushed to augment the communications architecture of V Corps, the 3rd Infantry Division, and other deploying units in less than a year. A comparison of the pre- and post-conflict architectures is at the heart of this study. It also examines the emergence of the network as the principal determinant for the growth in bandwidth requirements in the decade prior to the war. Additional chapters are devoted to programs that could rectify the current architectural shortfall and to the process that stymies the rapid acquisition of new technology for architectural improvements to communication networks.

This volume will be of interest to the United States Army and joint force designers, those concerned with the networking of the force, project managers who desire to streamline the acquisition process, and those persons interested in understanding and predicting the impact that exponential advances in technology are having on their organizations.

This research was conducted by the United States Army War College in cooperation with and for the Office of Transformation, Department of Defense.

Douglas B. Campbell

Director, Center for Strategic Leadership

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Preface

During the past decade, the United States (U.S.) Armed Forces have been in the process of transforming from an industrial age to an information age military. This transformation is still ongoing; however, Operations Enduring Freedom and Iraqi Freedom demonstrate the emerging power and potential of transformation, at least in part, through the power of information-networked forces.

In March 2004, the U.S. Army War College (USAWC) in cooperation with the Office of the Secretary of Defense (OSD) Office of Force Transformation (OFT) initiated a study focusing on the U.S. Army V Corps' and 3rd Infantry Division's major combat operations during Operation Iraqi Freedom (OIF). This study, entitled "Network Centric Warfare Case Study: U.S. V Corps and 3rd Infantry Division (Mechanized) during Operation Iraqi Freedom Combat Operations (March-April 2003)" is one of several case studies commissioned by OFT to determine the military's ability to conduct operations in accordance with network centric warfare (NCW) concepts. The OFT describes NCW as an "information superiority-enabled concept of operations" that will enhance combat effectiveness by networking sensors, shooters, and decision-makers.

The study hypothesis postulates that "improved sensors, connectivity systems, and networked information technologies enhanced the combat effectiveness of U.S. V Corps and its subordinate units during OIF major offensive combat operations." The results largely validated the study hypothesis. This study argues that the introduction of extended reach communications and networked information technologies significantly enhanced the ability of U.S. Army commanders to make faster decisions, more easily exploit tactical opportunities, conduct coordinated maneuver while advancing further and faster than at any previous time and more fully integrate and synchronize joint fires; all of which resulted in the rapid defeat of Iraqi military forces and the fall of the Ba'athist Regime in Baghdad.

The study is arranged in three volumes.

Volume I, entitled "Operations" uses the metrics provided in the Network Centric Operations Conceptual Framework as the guide in the conduct of the analysis concerning the applicability of NCW tenets during the conduct of major offensive combat operations. The analytical findings and observations of this volume validated that, during OIF, new sensors, extended connectivity, and new information systems enhanced the combat effectiveness of the force. This volume documents the impact of networked information on the application of combat power, battlespace synchronization, decision-makers and staffs lethality and survivability; force agility and operational tempo.

Volume II, entitled "A View of C4 Architectures at the Dawn of Network Centric Warfare" analyzes the command, control, communications, and computers architecture to ascertain the potential strategic and operational implications of net-centric operations from a command and control perspective.

Volume III, entitled "Network Centric Warfare Insights" is divided into two sections. The first section presents potential overarching strategic and operational impacts of network centric operations, based on findings in the first two volumes. Section two presents a series of battle

stories / vignettes illustrating the impacts of the various new technologies on actual combat actions and battles.

The U.S. Army War College served as the executive agent for this study. The research was conducted by the Center for Strategic Leadership's Information Warfare Group (IWG). The IWG study team used military personnel to manage the program and conduct the data analysis and contractors from MPRI (Military Professional Resources Incorporated) (an L-3 Communications owned company) to collect the data through personal interviews and documents, and write the report. USAWC also provided numerous other people and resources to assist in survey preparation and distribution, administrative support, and audio-visual support.

The uniqueness of this effort lies in its landpower focus. While previous case studies have quite adequately covered the "shooter-sensor" interface from a systems perspective, none have addressed the impact of NCW from the human perspective. This is the essence of land warfare, and why this study is so important.

Acknowledgements

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Special thanks go to Colonel (P) Jeffrey G. Smith, Deputy Commandant of the U.S. Army Signal School, Ft. Gordon, GA, formerly the 22d Signal Brigade Commander during Operation Iraqi Freedom, for his recounting of the communications posture before and during that war and the herculean efforts and bold initiatives to improve that posture by the collective Army workforce. We also thank the numerous others at Fort Gordon who were also a part of this study. They teach Signal Corps soldiers in an ever-changing curriculum that has become the hallmark of twenty-first century network-centric operations training.

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We also thank the many people at the United States Army War College who assisted us administratively, logistically, and technically in order to make this study possible.

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Executive Summary

INTRODUCTION

This study is designed to further the examination of the tenets of Network Centric Warfare (NCW), which hypothesizes that a “robustly networked force improves information sharing, collaboration, quality of information, and shared situational awareness resulting in significantly increased mission effectiveness.”

PURPOSE AND SCOPE

This volume is the second of a three volume set produced by the United States Army War College in conjunction with the Office of Force Transformation, Office of the Secretary of Defense. This volume is meant to provide the military reader with three insights: 1) to provide a historical view of the advances in technology that ultimately enabled a computer communications network; 2) to encapsulate the Army command, control, communications, and computer (C4) architecture for V Corps and 3 ID during the two specific timeframes referred to as pre-OIF and OIF-1; 3) to examine future communications programs that are underway for the next generation of C4 architecture with respect to the ability of the DoD acquisition process to keep pace with the rapid advances in technology.

OVERVIEW

This volume, “A View of Command, Control, Communications, and Computer Architectures at the Dawn of Network Centric Warfare,” provides a historical view of military communications since WWII and then notes the advent of the computer, which enabled network centric operations. It also highlights that change is demonstrably increasing exponentially; that is, the rate of change itself is increasing. This function is portrayed as a curve (an S-curve). This leads to the conclusion that change should be anticipated and, at some point along the curve, a paradigm shift will occur to initiate the start of a new S-curve. Paradigm shifts are difficult to predict and are prone to spontaneous eruption, as was the case of the World Wide Web. Accordingly, it was virtually impossible to anticipate the explosive demand for battlefield video and data that would restrict tactical commanders’ ability to command and control highly mobile forces on a vast battlefield. The OIF-1 communications architecture outlined in this volume, as compared to the pre-OIF architecture also described, serves to underscore the predicament that exists when communications architectures fail to keep pace with rapid advances. Despite the valiant efforts to bridge this gap in only months before OIF combat operations, nothing could provide the total bandwidth needed, the collaboration tools desired, nor the ability to command and control on the move, all of which are now deemed essential for the modern battlefield. This war revealed that a communications paradigm shift occurred, and commanders recognized that the next generation communication architecture was yet far out on the horizon. Thus, this volume looks at the programs on that horizon at the dawn of NCW and then points to the urgent need to reinvent the acquisition process to procure them expeditiously, at least before they become obsolete.

This volume is necessarily incomplete. During its March to August 2006 writing, Congress halted further fielding of the Joint Network Node solution for OIF until it receives a report from the

Secretary of the Army on 15 March 2007. Additionally, the Warfighter Information Network–Tactical, already in its eighth year since its operational requirement, was delayed an additional five years—it will be 2013 before it can field its initial operational capability. Consequently, there is no closure to the C4 communications architecture under study here. There are, however, several general themes, represented by quotes at the start of each chapter: 1) *invention,* 2) *simplicity,* 3) *the Army you have,* 4) *innovation,* 5) *acquisition cycle times,* 6) *delays,* 7) *vision,* and 8) *cleverness.* Each chapter exposes tactical communication architectures with respect to accelerating technological change. This volume is an appeal to readers to invent the future rather than merely attempting to predict it.

1. C3—Command and Control Communications before Computers

The best way to predict the future is to invent it.
—Alan Kay
American Computer Scientist

What a difference fifty years make. To begin to comprehend where we are going with respect to Command and Control Communications and Computers (C4), it is necessary to have some knowledge of where we have been and how we came to be where we are. Specifically, the present era of warfare, in which computers have been embedded in weapons platforms and communications systems, is at best only three decades old, about the same number of years as a major general commanding a division has time in service.

To be sure, exposure to the computer did not come early in the careers of most serving general officers. As with the civilian populace, it took the dawn of the personal computer and, more specifically, the dawn of the network known as the World Wide Web in the last decade to make almost all military service people computer literate. The notion of network centric warfare (NCW) is a recent addition to the study of warfare. It was not in senior commanders' vernacular throughout most of their military professional development; it was not even in their senior service schooling in 1995. The terms C4 and NCW are not to be found in the Persian Gulf War scenarios of 1991. It was this war, however, that revealed the limitations of the Cold War communications' architecture for future war. The defensive battlespace[1] of Europe had to give way to a highly mobile battlespace that required communications on the move on a rapidly changing, fluid battlefield covering vast distances. The need for C4 on the move for the prosecution of Operation Iraqi Freedom (OIF) in 2003 would be unprecedented.

The fourth 'C' in C4 is the computer. Today the computer is ubiquitous and embedded in almost every aspect of modern society's activity. In one form or another, it wakes us in the morning, automatically turns on the coffee, records phone messages, regulates the functions of our automobiles, computes at the cash register, and manages the micro and macroeconomic functions of civilian society. It keeps our work and leisure activities functioning on an even keel. We have come to expect its presence and full functionality, and when it is operating properly, we are oblivious to its management of so many aspects of our daily life. When it is not operating properly, we are instantly and unhappily aware of its absence. Their importance in our daily lives becomes manifestly obvious. For example, observe what happens in a grocery store checkout line during a power outage. We have become inextricably reliant on the computer and have few or no backup processes when it fails. The implications of the computer in warfare are significant indeed, but if the computer fails, or simply becomes unavailable, the ramifications could be catastrophic. For this reason it is essential to understand how command and control communications have become computer enabled and how the lessons of the maneuver phase of OIF (OIF-1) have inaugurated the

official launch of NCW and have provided lessons learned for the next generation of professional military development.

The crucible of war is a mother for invention. World War II era technological innovations were the precursors of what we see today. Now, because of the ubiquitous use of technology, communications, and computers, we are in an era of ever-expanding, and apparently unbounded, expectations as the tools of our peacetime applications spill onto the battlefield. Soldiers ask themselves, "If I can drive to work with my cellphone on the move, why can't I do it from my command post vehicle; if we can put a man on the moon…?" In the World War II era, military inventions created advancements in civilian technologies. Now the converse is the norm. New civilian technology can enable battlefield applications, but the time required to actually insert the technology into the system is longer than the useful life of that new technology. Moore's Law[2] and commercial innovation have outstripped the capability of the military acquisition and life cycle management process to rapidly equip the force. Nor can the process keep pace with the "accelerated expectations"[3] of those commanders who believe that "off the shelf" means "instantly available."

Moore's Law:

In 1965, the physical chemist Gordon Moore, co-founder of Intel, predicted that the number of transistors on an integrated chip would double every eighteen months. Moore predicted that this trend would continue for the foreseeable future. Moore and most other experts expect Moore's Law to remain valid for at least another two decades.

Indeed, the first electronic and programmable computer, code-named Robinson, was invented in England in 1940. It was used principally to break German codes. Just three years later, a computer named Colossus would debut with one thousand times more speed. The Mark I was invented in the United States shortly afterwards, and in 1946, the Electronic Numerical Integrator and Computer, or ENIAC, produced a similar thousandfold increase in processing power. However, by 1946, the primary role of the computer had shifted from wartime applications to scientific endeavors. International Business Machines (IBM) introduced the IBM Model 701—which initially was named the Defense Calculator—and almost immediately received eighteen orders for use in designing aircraft and jet engines and for other applications requiring repetitive operations.[4] To be sure, much of the ability to calculate was directed towards nuclear weapons research,[5] but it is also true that business management information systems and the invention of the software language known as Common Business Oriented Language (COBOL) validated the notion that wartime inventions produce commercial applications. The exponential rise in the number of computers was not envisioned, particularly outside of the scientific community.

Computers were so large and expensive and were used for such a specific set of applications, that the need for such machines was initially viewed as very limited worldwide. Few, if any, could predict the widespread use of computers beyond code breaking and specific defense program usage. T.J. Watson, the founder and chairman of IBM, is quoted as saying, in 1943, "I think there is a world market for maybe five computers." The transistor was invented in 1946, and within a decade it began to replace the vacuum tubes in computers and radios. However, even at the end of the 1950's, computers still weighed tons and required kilowatts of energy; no one could imagine transporting them on the battlefield or embedding them in a radio.[6] The emergence of solid-state devices and discrete components in the late 1960's would fuel the advance of battlefield communications for the next two decades. The tactical communications of that era were not automated in the sense that they contained any semblance of computers, programmability, or networking. For all of the shortcomings that will be discussed about Mobile Subscriber Equipment (MSE) during OIF-1, it

is useful to realize that MSE— with the exception of the AN/TCC-38 and 39 for automatic tactical voice switching and the AN/TYC-39 for tactical message switching—was the first generation of battlefield tactical communications equipment to be enhanced with embedded computers.[7]

From a doctrinal perspective, responsibilities for providing communications have not changed. The lines of responsibility are from higher to lower, left to right, and supporting to supported. For this study, this means that V Corps was responsible to extend its communications lines to the 3rd Infantry Division (3 ID), and similarly, 3 ID was responsible to extend communications to its brigades. A unit on the left (U.S. or ally) extends communications to its right, as oriented toward the forward line of troops. In any case, if there is incompatible communications equipment between organizations, the higher unit, the left unit, or the supporting unit is responsible to physically bring its communications equipment and personnel to its lower, right, or supported unit respectively. For the frequency modulation (FM) voice traffic VRC-12 family of radios, in use since the 1960's, this did not pose significant problems, since this radio was distributed homogeneously throughout the force. As an alternative example, based on the supporting to supported responsibility, weather data at the division is the responsibility of the Air Force, and consequently, an Air Force officer with an Air Force vehicle was attached to the division tactical operations center (TOC) with specific Air Force weather radios. For multichannel systems, high frequency (HF) radio-teletype, and record traffic (comcenter) operations, the higher to lower doctrine applied. Thus, the division signal battalion would deploy a signal platoon to the division brigades to accomplish this communications mission. Similarly, the corps' signal battalion deployed signal platoons to the corps' divisions. Technically, this doctrinal support paradigm has not changed. It is orderly and reasonable, although not necessarily efficient, to transport voice and data in the digital era of communications in this way today. We will see a new paradigm in Chapter 4 with the emergence of the tactical internet and in Chapter 6 with the elimination of the division signal battalion to make way for the concepts of modular brigades and network nodes.

Record traffic (what is often referred to as official hard copy messages) before the digital age was also known as "torn tape relay," and it persisted virtually unchanged from World War II until the early 1980's. Using a teletypewriter, a limited character set was encoded as holes in paper tape. The paper tape was prepared by communications soldiers who retyped messages that had been submitted on a DD Form 173. The DD Form 173 had been prepared by a staff officer, reviewed by a senior staff officer, and then released by a more senior officer. The paper tape preparation was even more tedious since a mistyping resulted in a bad tape. After the tape was punched, it was inspected and annotated by a comcenter supervisor for accuracy, and then sent through a tape reader and transmitted to a distant station at sixty-six words per minute. This step was predicated on the stable availability of the transmission radio equipment, either multichannel equipment (very high frequency (VHF) or ultra-high frequency (UHF) line-of-sight) or HF over-the-horizon radio teletype equipment. An interruption, however brief, in the transmission required a retransmission of the entire message. A good transmission was logged and manually read to ascertain the final destination of the message and to determine its next transmission leg, hence the term "relay." Messages were typically in the delivery mode for hours, lost messages were all too common, and traceability required superhuman effort. The example of the German III Corps to the left of the U.S. V Corps in the 1970's standard Cold War Europe defensive posture illustrates the difficulty of communications with allies. The German corps would send its incompatible comcenter, multichannel equipment, and soldiers to live and work at the V Corps headquarters.

There was one particular problem with this augmentation: U.S. paper tape was 0.75 inches wide, whereas German paper was approximately 0.5 inches wide, a physical incompatibility. Thus a German message passing through V Corps had to be printed from its tape and punched on 0.75 inch tape for further transmission to U.S. echelons. From end to end, it was marginally better than motor messenger, which was a scheduled route, not unlike the postal service, used during tactical operations.

It was this communications process that established the tactical commander's level of expectations for message dissemination for the fifty years prior to a tactical internet. The flow of the battle was determined by the ability to flow communications. In General of the Army Omar Bradley's words, "Congress can make a general, only communications can make him a commander."[8] Therefore, the operations tempo (optempo) would necessarily be a function of the sufficiency and efficiency of the commander's communications. The passage of a message across the corps or division was expected to take hours. Worse, there was an accepted probability that the message would not arrive at some units at all. The earliest improvements in the process of message handling occurred in 1978 at V Corps when optical scanners were acquired that could read a redesigned DD Form 173 using a special IBM Selectric™ typewriter font. However, this only automated the paper tape punching process, a fractional part of paper tape preparation. It was a foreshadowing, however, that computer automation was about to arrive at the corps echelon and below.

The ability to track forces at the V Corps TOC in the 1970's and 80's was about as archaic as the message traffic situation just described. To track units, principal corps staff elements were arrayed in front of a large Plexiglas™ window with a translucent map of the battle area. There was just enough room on the other side of the window for two soldiers, trained to write symbols and characters backwards with grease pencil, to post unit positions in the corps area. Friendly positions were relayed through communications systems by grid number. Enemy positions were provided by spot reports to the All Source Analysis Section via special circuits. Unit postings on the map board were static and had considerable and indeterminable lag time. Desert Storm would herald the Small, Lightweight Ground Receiver (SLGR) and the Joint Surveillance Target Attack Radar System (JSTARS), but corps and below unit tracking remained virtually unchanged until OIF, when the use of Blue Force Tracker (BFT) made its debut on the battlefield.

The personal computer (PC) arrived commercially in 1981, introduced by IBM. Until that time, mainframe computers, mini- and super-mini-computers under the trade names of IBM, Universal Automatic Computer (UNIVAC), and Digital Equipment Corporation (DEC) were housed in temperature-controlled environments and touched only by trained computer technicians. At the beginning of the 1980's, the Defense Advanced Research Projects Agency (DARPA) was experimenting with transferring files from one of these types of computers to another over long distances, typically between universities. File transfer protocols (FTPs and later TCP/IP)[9] were developed, and soon a seven-layer scheme for moving data virtually across a multi-computer network was realized. This experiment was known as DARPAnet, it was the birth of the Internet as we know it today.[10] But it took most of the 1980's to see any growth in the network. In 1977, the president of DEC (a major producer of mainframe computers) had postulated that "there is no reason anyone would want a computer in their home."[11] Ironically and just four years later, the introduction of the PC put the computer and its strange new vocabulary in the hands of a limited number of office workers and households. Its application was mostly relegated to word processing, storing recipes, and playing primitive games unless one had a scientific application and needed

to use languages such as FORTRAN or Pascal.[12] There were few applications, commands were obscure and typed (there was no “mouse” to point and click), and most importantly it did not communicate past the desk or building to the outside world. Indeed, it took the maturation of the Internet, in concert with a graphics scheme and the hypertext markup language (HTML), to realize the World Wide Web in the early 1990’s. Before that time, very few people had an e-mail address or a website with which to identify themselves. Telephone and facsimile numbers sufficed. There was no widespread use of e-mail during Desert Storm, but the exponential increase in the number of personal computers, electronic mail messages, and websites was about to begin two years later. It would spill from the commercial sector to the battlespace within ten years. The era of Network Centric Warfare was about to dawn.

When was the ‘C’ for computer put in C4? From a linguistic point of view, C4 was born in the 1990’s. The computer at the corps and below, however, emerged in the late 1970’s. Until then, the tactical telephone switch at the corps was a manual switch (operators with patch cords) and the soldier at the TOC called the local operator with a hand-cranked phone (TA-312) to place a local or long distance call. Long distance meant manually routing a call, through multiple operators if necessary, to find the desired subscriber. Fixed sites were essential for this to work. The subscriber could not roam and simultaneously receive a call. By 1970, commercial phones were being converted from rotary dial phones to touch tone (dual tone, multi-frequency (DTMF)). The fielding of the AN/TCC-38 (and soon the AN/TCC-39) brought commercial technology to V Corps in 1977. These computer-driven switches not only provided familiar DTMF dialing, but they also provided precedence calling and alternate call routing (altroute) features. Altroute was a tremendous step in tactical switching, but not as great as what would later be provided by mobile subscriber equipment (MSE). The AN/TCC-39 telephone switch, in two S-280 shelters mounted on 2.5 ton trucks, provided automatic switching for three hundred local subscribers. Because the switch was a computer and used the corps multichannel system for long distance, it was now possible to program a primary and alternate path for long distance calls. Thus, it could sense that if a line to Division A was not operational, a pre-selected route through Division B or another node could be selected automatically. Although this bifurcated routing provided only a limited increase in capability, it did provide users with assigned phone numbers and a significantly higher probability of call completion.

In some sense, this alternate path pre-selection was a precursor of future dynamic networks that would use addresses and routing options.[13] Similarly, the AN/TYC-39 message switch had a store and forward message capability. Message forms were not only optically scanned, but they could also be stored digitally. A path for the message could be selected as for the voice switch, and the distant end could receive and store the message. If the message needed to be routed still further, no punch tape was necessary. The message was temporarily stored in the computer memory and forwarded to the next comcenter node as programmed in the switch. Programming was slow, tedious, and ever changing, but it eliminated punched paper tape. Digital storage was a vast improvement over paper.

In 1979, almost as soon as these automated voice and message switches were fielded, a required operational capability for a new switch was announced. Based on the French tactical telephone switch named RITA, this new U.S. military switch would utilize a “flood search” capability. A flood search sent a call through all possible routes from the origin until the destination number was found. Thus, a subscriber could roam to other locations with the same phone number and

not be tied to a single location. This was only possible because of software algorithms and faster computers. It significantly improved call completion rates. This new switching system, along with a system of land and radio extension nodes, would become known as MSE. Within ten years it would replace all of the multichannel carrier systems and voice and message switches at corps, division, and brigade level in the active Army. Desert Storm would be fought using MSE, but only a dozen years later MSE would prove totally inadequate for OIF-1.

The implication of the history of computers is important for understanding the future of C4 architecture. Pre-computer C3 architectures existed in twenty- to fifty-year increments. After the introduction of programmable computer switching and the advent of the Internet, the communications technology growth curve would never again be as flat. A significant investment was made in MSE for the backbone of the Cold War era defensive C3 communications architecture. Thankfully, it never had to put to that test. But this new MSE technology would be inadequate for the demands and requirements of commanding and controlling a rapidly moving force in the attack. Real-time communications, as in garrison and civil life, needed to be available on the battlefield.

Once satellite communications were available to bring live news and sports from around the world into the living room, tactical commanders in the war room demanded the same capability. The playing field accelerated communications expectations for the battlefield. In contrast to those first World War II computers that ignited the commercial sector, the onslaught of commercial computer products and devices would be a driving force of the military C4 architecture on the battlefield of the twenty-first century.[14]

The mass acceptance of new technologies was being driven by the synergistic effect of Moore's Law: advances in computer technology accelerated the pace of advance, faster computers lead to yet faster computers, and each succeeding generation came more quickly. This phenomenon drove exponential growth curves, economies of scale in production of new products, near-immediate exposure of new technologies globally, and the dynamics of a highly competitive commercial marketplace. The realm of the possible grew daily. The language of technology (bytes, RAM, bandwidth, network, wireless, router, mouse, click, dotcom, nanosecond, and more) invaded the vernacular and began to shape the way we think. Visions of communications architectures were developed based on technology never imagined fifty years ago. The Nobel Prize laureate Bertrand Russell said it best: "Language serves not only to express thought but to make possible thoughts which could not exist without it." Today, a networked battlespace future is not merely possible, it is predictable because the language and tools are available to invent it. Alan Kay was correct, "the best way to predict the future is to invent it."

2. A Methodological Model for C4 Architectures

Everything should be made as simple as possible, but not simpler.
—Albert Einstein

Communications were once very simple. It existed at primitive and fundamental levels in the physics and chemistry of matter interactions from the dawn of time. Natural laws construct the world that we see using shared electrons among the elements to construct molecules and genetic codes to arrange the architecture of life. Life has created architectures to ensure its very existence by using sight and sound to communicate a wide variety of attractions, whether in flora or fauna. Communication is a necessary property of the universe to achieve goals. In humans, ideas and speech for communicating ideas are unique to life on earth. In the beginning of the human race, no doubt, communications were crude and simple. But as ideas became more complicated, so, out of necessity, did the mechanisms to communicate them. Not only was complex speech invented, but the means to transmit it (such as by beating drums and trumpeting horns) with varying degrees of complexity was also developed. For economy and speed of transmission, the architecture for early communications was as simple as possible. This chapter will focus on the necessity for and the complexity of modeling C4 architectures in modern communications for the twenty-first century battlespace.

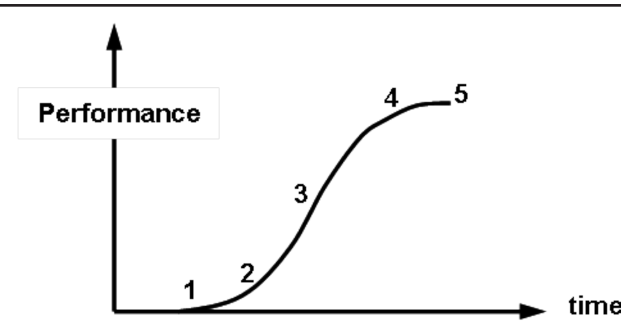
The battlespace, as noted earlier in Chapter 1 and as defined in FM 3-0, has not fundamentally changed in the history of warfare, only its scope. Recall that by definition battlespace is *"the air, land, sea, space, and the included enemy and friendly forces, facilities, weather, terrain, the electromagnetic spectrum, and the information environment within the operational areas and areas of interest."* But there are two exceptions to this seemingly unchanging definition under analysis: the electromagnetic spectrum, the potential of which has only been harnessed for the last 150 years, and space, which has only been available to military commanders for about 40 years. The use of the electromagnetic spectrum was ushered into the battlespace by the invention of the telegraph in 1844.[1] By the U.S. Civil War twenty years later, more that twenty-three thousand miles of telegraph wire had been strung across the country. Mobile configurations were expressly developed for the battlefield. By the end of the nineteenth century, radio had been invented; it was first used by the Army in 1899. Although radio saw limited application in World War I, its use in warfare for voice and radar significantly increased during World War II (WWII). The use of space was made possible when artificial satellites were placed in orbit around the earth. The use of space for warfare only goes back to the 1960's when early applications were confined to the study of anti-satellite developments and the effects of electromagnetic pulse from nuclear weapons detonation. Most of these applications were banned by treaty by the end of the decade. Now, satellites for the battlespace are primarily for surveillance, communications, and the global positioning system (GPS).

Advances in all of aspects of the battlespace have occurred throughout the history of warfare—except electronics and space. Electronics did not have an effect until the 1930's, and space until the 1960's. Without the ability to operate in space and in the electromagnetic spectrum, the rate of battlespace

change would have continued along a relatively flat, "evolutionary" curve governed by the art of war, its history, lessons learned, leadership, and revisions to doctrine. Without electronics and space, advances in the science of warfare were limited to advances in mechanics and mechanical advantage, advances made at the speed of our human biology. With the harnessing of the electromagnetic spectrum and space, the science of warfare has begun to advance at a computer-enabled, ever-increasing speed. Thus, the modern battlespace was transformed. Constrained only by the speed of light, the dissemination of information enabled by electronics can circumnavigate the globe seven times in one second and the means to transmit even greater volumes of information is increasing exponentially.[2]

This transformation is illustrated by the S-curve model. There are five stages along the path of the S-Curve as shown in figure 1. A *rupture* occurs with the introduction of a breakthrough technology that radically increases the spectrum of capabilities: gunpowder, the tank, atomic power, and so forth. The *early development* stage includes marketing, refinement, and testing. As a new technology finds widespread acceptance and use, it enters the *expansion* stage and improvements continue. Eventually, the technology matures: this *maturation* stage is typified by global acceptance and use, but the rate of product improvement plateaus until the technology reaches its *saturation* point. At saturation, diminishing returns are encountered when a disproportionate amount of effort is expended relative to any increase in output.

In the human experience, we have seen the jet engine surpass the fastest propeller-driven, the electron microscope transcend the optical microscope, the telegraph doom the Pony Express. These examples represent a shift to a new S-curve. These paradigm shifts are sometimes called transformation. In 1930, the rapid shift to electronics in war was a transformation of the battlespace. Signal flags, pigeons, telegraphs, paper-tape relay, and hand-cranked phones have been relegated to history and are only seen in museums. They have been replaced with computers and electronics, decision aids, displays, and networks. These new tools and devices have become central and essential to the modern way of war, and they are helping to create a new battlespace. The cumulative effect of the plethora of communications systems has come to be known as C4. C4 is at the very heart of the notion of network centric warfare. C4, however, is complex. Managing and understanding complexity requires an architectural framework. The higher-to-lower, left-to-right doctrine of the twentieth century is too simplistic today. Driven by a variety of shortfalls identified in the lessons learned from the Persian Gulf War of 1991, the Defense Science Board developed and proposed a new C4 architecture framework.[4] A key finding was that the best means to achieve interoperability and cost effectiveness was to provide communications architectural guidance to the DoD.[5] The resultant study became known as the Command, Control, Computers, Communications, Surveillance and Reconnaissance, or C4ISR, Architecture Framework (the Framework) Version 2.0 dated 18 December 1997. It



Phases of technology innovations: (1) rupture, (2) early development, (3) expansion, (4) maturation, and (5) saturation

Figure 1. Technology Phases along an S-curve, from Crowley.[3]

would later be revised as the DoD Architecture Framework (DoDAF) Version 1.0 Deskbook dated 9 February 2004.[6]

The Institute for Electrical and Electronics Engineers (IEEE) defines the term architecture as "the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time."[7] The Framework is careful to differentiate between an architecture description and an architecture implementation. The description means the "blueprint," while the implementation means the real-world capabilities and assets in the field. The Framework does not address how the blueprint-to-implementation process takes place. The Framework does, however, divide an architecture into three views—the operational, systems, and technical views. These views, depicted in figure 2, are defined as follows:

- Operational Architecture View—a description of the tasks and activities, operational elements, and information flows required to accomplish or support a military operation.
- Systems Architecture View—a description, including graphics, of systems and interconnections providing for, or supporting, warfighting functions.
- Technical Architecture View—the minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of requirements.[8]

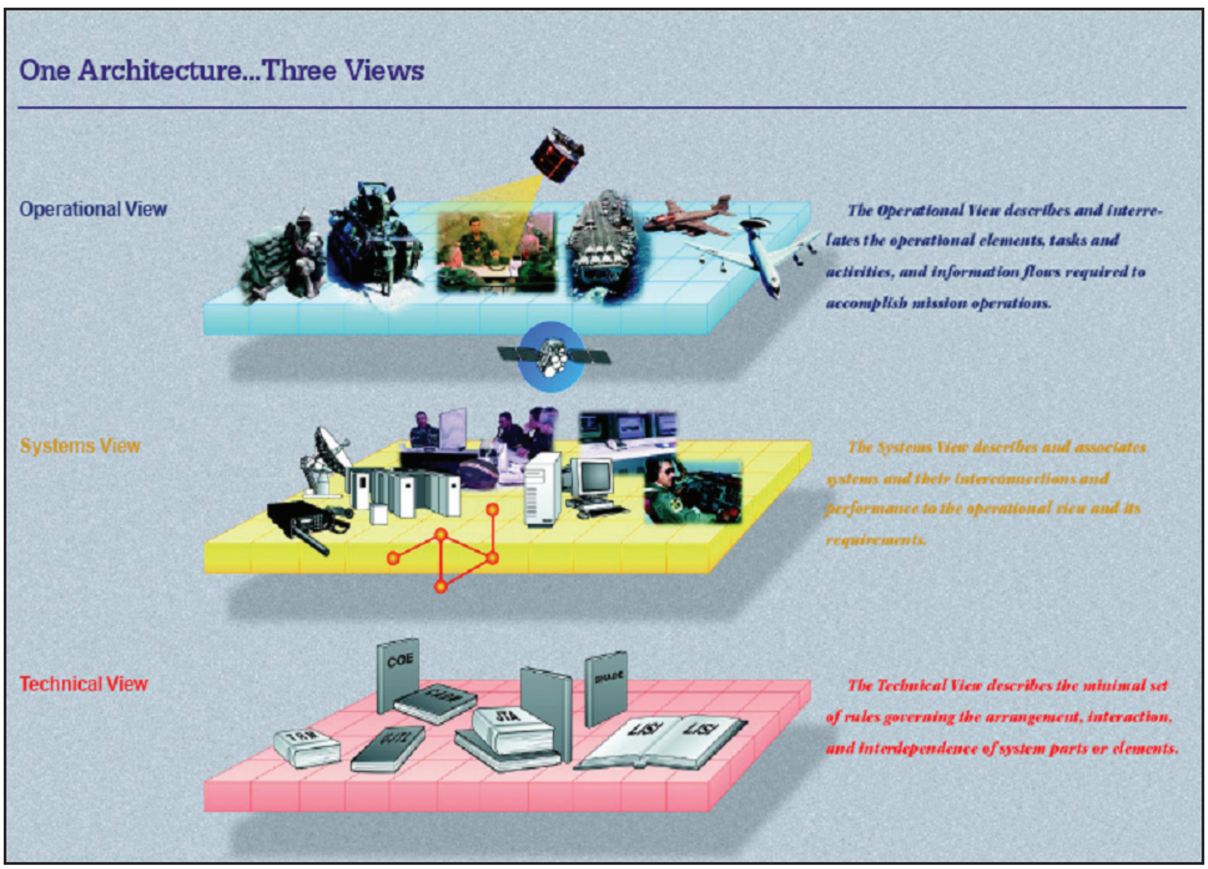


Figure 2. The Views of a Communications Architecture.

Source: http://www.defenselink.mil/nii/org/cio/i3/AWG_Digital_Library/pdfdocs/brochure.pdf

The principal focus for this volume of the case study is the systems architectural view. The desired outcome for C4 systems is the capability for all warfighter information systems to be able to "plug and play" in an all-services and global environment. Moreover, the three architectural views delineated above serve to work in concert to enable shared data elements, connectivity, technical dependencies, and conceptual independencies. Taken together, the three views provide a framework to ensure interoperability, regardless of system origination, as long as the system adheres to the standards expressed in the architecture.

Despite Einstein's plea for simplicity, all of the C4 architectural views described by the Framework are complex. However, the three views, which define interoperability, plug and play, and the IEEE's "evolution over time," may in fact be the "simple as possible" urged by Einstein. There is true engineering rigor in the strict implementation of the Framework. Less than this would render a modern system architecture insufficient. As project managers—who know all too well that they must control the parameters of cost, schedule, and performance—like to say, "You can have it cheap, fast, or correct—pick two." Cheap results from simplicity; correct requires complexity. Although we might not be able to do away with the complexity of the three architectural views in practice, we may be able to view architectures using a simple analogy, the Rubik's Cube.

In the pre-computer era of communications, system longevity timelines were fairly stable, and families of FM radios, multichannel communications, and message center operations systems could last for twenty years or longer. Life-cycle management was sustained over decades, as were repair parts stockage and the tables of organization and equipment (TOE) for military units. Stability across the full range of doctrine, organization, training, leadership, materiel, personnel and facilities (DOTLM-PF) domains was the norm. To properly field MSE, division and corps signal battalions turned in their old family of equipment en masse and were issued a complete set of MSE equipment on a predetermined schedule. New equipment training (NET) was given on site to the entire unit. Change is always hard, but change with a deliberate schedule and plan makes the hard easier. Change without organization or control and with unbridled frequency makes the hard much harder. In Chapter 4 we will discover the consequences of this kind of hard change during OIF. In this chapter, we will consider a methodological model for depicting C4 architecture changes through the analogy of the Rubik's Cube.

The Rubik's Cube is a well-known toy developed by Erno Rubik of Budapest, Hungary in 1974. It is estimated that one-eighth of the world's population has used one. Each face of the cube consists of nine colored "cubies." In the initial state, each face has a distinctly different color. Rotating the rows and columns of the cube causes cubies of different colors to intermix. It is useful at this point to read what Mr. Rubik said after early observations of his cube:

> *It was wonderful, to see how, after only a few turns, the colors became mixed, apparently in random fashion. It was tremendously satisfying to watch this color parade. Like after a nice walk when you have seen many lovely sights you decide to go home, after a while I decided it was time to go home, let us put the cubes back in order. And it was at that moment that I came face to face with the Big Challenge: What is the way home?*[9]

Rubik's observation is indicative of the C4 architectural dilemma today—what is the way home? In the days of C3 architectures, the days when architectures lasted decades, the "color" of the existing architecture was homogeneous. There were no interposing "cubies" to complicate the picture. For instance, the AN/GRC-50 radio was a vacuum tube radio that transmitted the carrier signal for the

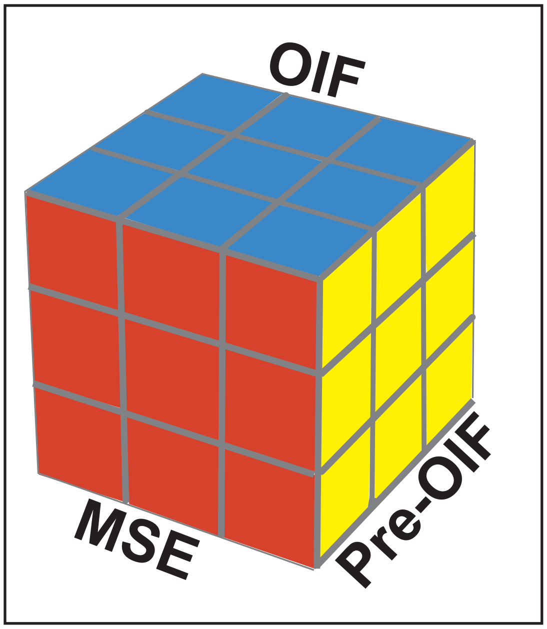


Figure 3. Homogeneous Architectures Depicted by a Rubik's Cube.

multiplex equipment at division and corps. It entered service in the 1950's. It was replaced throughout the active Army by the AN/GRC-103 radio at division level in the 1970's and at the corps level in the 1980's. This complete change to new radios was analogous to rotating the entire cube to a new homogeneous color. The orderly fielding of MSE in the late 1980s is another example of rotating the cube to a homogeneous new color that represents an entirely new architecture. Ideally, an architecture, in any snapshot of time, should be homogeneous, as shown in figure 3.

The entire family of multichannel equipment was replaced by a new family, first at division, then at corps. Again, the entire cube has been rotated, not an individual row or column. This is also true of the tactical FM radios when all of the VRC-12 radios, which had persisted for more than thirty years, were replaced by the Single Channel Ground and Airborne Radio System (SINCGARS) in the 1980s. To be fair, SINCGARS fielding did take a long time due to production schedules, but it was a complete exchange of equipment, with a very long life-cycle management timeframe. The FM voice architecture was never intended to leave the intermixing of VRC-12 radios and SINCGARS radios in a permanent state. The path "back home" was envisioned as a homogeneous family of SINCGARS radios, one solid color on the Rubik's Cube face of voice radio architecture.

New equipment fielding should be as quick and complete as possible. However, fielding a new communications system requires consideration of all DOTLM-PF components. Training and logistics are key factors. Training soldiers concurrently on more than one family of equipment in the military schoolhouses is inefficient. Training soldiers on only specific types of equipment in their specialty adds complexity to the personnel assignment process. Stocking parts in the logistical train is difficult when there are multiple types within a family of equipment. Duplication in any

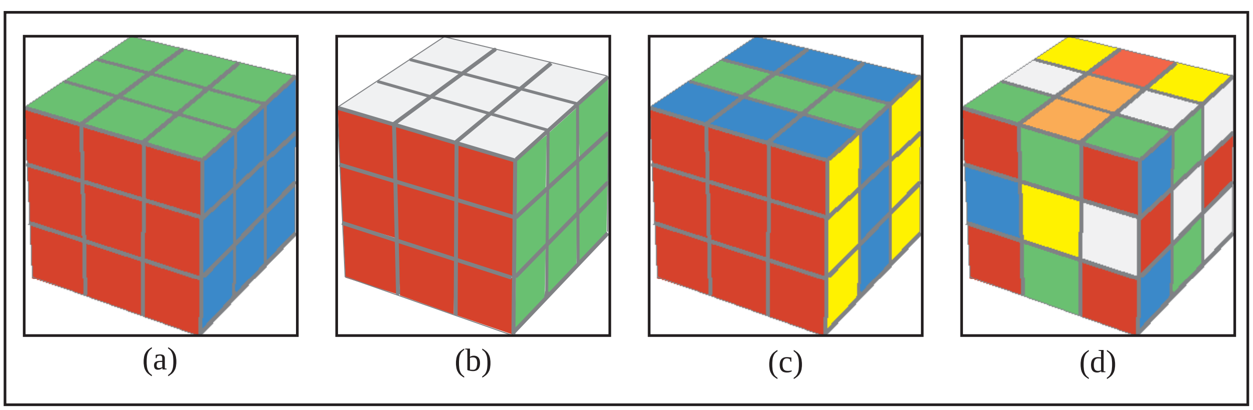


Figure 4. Architectures Envisioned as Rotations of a Rubik's Cube

form is expensive and inefficient. We will revisit these issues in Chapter 6, where the current Joint Network Node (JNN) fielding is examined.

The future of equipment fielding for new C4 communications architecture is not promising. Budget cuts across project management programs (sometimes known as “salami slices”) tend to leave fieldings incomplete over long periods of time. Sometimes there is no path home for Mr. Rubik. The cube face is never a homogeneous color again. Desired evolutions of pure architectures, as depicted in figures 4a and 4b become mixed and interwoven as shown in figures 4c and 4d.

The continuation of Moore’s Law out to at least 2020 ensures that new technology insertion will be frequent. The impact of Moore’s Law is the result of its own premise. When the number of transistors on a chip doubles, embedded computer processor speeds increase and size and power requirements decrease. This dual effect translates into an increase in capability. In the marketplace, new features in the same product family emerge at ever-increasing rates. This is good for commercial business (consider the pace of cell phone upgrade incentives) but bad for military C4 stability and program management. Long development and approval cycles necessitated by the implementation of law (Cohen-Clinger Act) and DoD Directive 5000.1 ensure that the commanders’ patience will be exhausted long before their pressing operational needs have been met. When they see technology on the commercial shelf that would provide them—or their potential adversaries—with a qualitative advantage in the next war, they will not wait for a programmed fielding. This results in so-called “drive by fieldings” of non-type-classified items and systems, TOE irregularities, and the circumvention of the rigor required by the Framework. As will be seen in the review of the prosecution of OIF-1 in Chapter 4, combat capability trumps the requirement for a modified TOE (MTOE). DOTLM-PF considerations take a back seat as well. The reverberations from these effects leave post-conflict “tsunami waves” on the pre-conflict C4 architectures in general and on the ongoing C4 programs of record in particular. “General” Rubik has created such a rich array of colors by turning the cube so many times along the path of war that he his faced with the Big Challenge, how to get back home to a standard C4 architecture?

The solution may lie in the lessons learned in Chapter 1 with regard to the advent of the computer developed during WWII. The war gave impetus to the development of the computer and other electronics for communications. There was, in fact, a pre-war development plan for commercial electronic computer and radio technologies. Television was actually invented before the war, but it was the development of the wartime production capacity of picture tubes for radar that made the explosive growth of civilian television sets possible after the war. There is, however, a distinct difference between World War II and OIF. The exponential growth of WWII electronics arose because of the war. Commercial applications came afterwards. In OIF, products were available commercially off-the-shelf and inserted into the war. In WWII, in situ product development was the “program of record,” whereas in OIF, commercial off-the-shelf products disrupted ongoing military programs of record. A program of record is “home” in the Rubik’s Cube sense. It is governed by an architecture blue-print and the standards imposed by the Framework. Architecture is regulated by laws and regulations, as previously mentioned. A program of record is methodical, rigorous, and life-cycle managed. Off-the-shelf products are random, good-enough, and ad hoc supported. The immediate increase in warfighting capability from “drive-by” fieldings is a very appealing tradeoff over programs of record. It is likened to instant gratification at a buffet without regard for the ill-effects on digestion in the long run. Getting back on the healthy path of a Framework for programs of record requires vision and discipline. Finding the path is not necessarily the retracing of steps already taken. It may mean charting a shortcut to an alternative path on the way to the original goal, or it may mean setting a new goal altogether.

In Chapter 5, we will more fully explore the Warfighter Information Network-Tactical (WIN-T). WIN-T is a program of record that dates back to 1997, when its required operational capability (ROC) was approved by the Army's Training and Doctrine Command (TRADOC). WIN-T has all of the best attributes of a deliberate and testable architecture to ensure interoperability among its own systems and approved external interfaces. Its future was pegged to a long-term goal of another architecture known as the Global Information Grid (GIG). WIN-T would connect to the GIG for worldwide access to a global information-sharing network. Products from WIN-T are designed to interface with or become the products of the Army's centerpiece for force transformation, the Future Combat System (FCS). Both the GIG and FCS will be explained more fully in Chapter 7. Suffice it here to say that these three programs of record (WIN-T, GIG, and FCS) utilize the best programmatic standards of the acquisition process today. All three are rooted in the pre-OIF timeframe. All three have a vision of utilizing future technologies over a 20-year horizon.

Twenty-year time horizons are not new with regard to envisioning future technologies. There is an interesting parallel between post World War I visioning, circa 1920, and future C4 architectures of today. Most might think that technology was so immature in 1920 that there was no "futures" visioning in that era. Quite the contrary. Table 1 indicates that military technologists were projecting five-, ten-, and twenty-year forecasts not unlike the 2002 Chairman of the Joint Chiefs of Staff Joint Vision 2020, shown in table 2. As much as there are parallels when comparing these two eras, there

Technology	Short Term (5 years, ca. 1925)	Interim (10 years, ca.1930)	Long Term (20 years, ca. 1940)
Aircraft Engines	Development of radial piston engines	1000 horsepower (hp) radial engines	2000 hp radial engines
Bombsights	Fixed bombsight + low-level bombing	Dive bombing; gyroscopic sight	Computing sight
Aircraft structures	Wood + fabric	Metal + fabric	All metal
Electronics	Vacuum tube amplifiers, active + passive sonar, intercepting and jamming low + medium frequency radio signals	Intercepting high frequency (HF) signals, effective HF, reliable active sonar	High Frequency Direction Finding (HFDF) Frequency Modulation (FM) radios, radio navigation, radar, and jamming radio signals
Jet Engines	Laboratory Experiments	First design patented	Development
Computers	Naval artillery fire control with analog devices well established	Stable elements in bombsights and in naval gunfire computers (all analog)	Routine use of automatic data processing equipment + mechanical calculators
Helicopters	Concepts	Lab experiments	Prototypes
Amphibious vehicles	Ships, boats, and commercial off- the-shelf technologies	Prototype landing craft	Landing craft and tractors
Air defense command and control (C2)	Binoculars and telephones	Binoculars + telephones, sound detection devices	Radar, FM radios, networked control and surveillance

Table 1. Notional U.S. Projections in 1920 of Transformational U.S. Military Technologies.[11]

Military Task	In Current FYDP	Interim Force	Supporting JV2020
Air Combat	Stealth supersonic cruise, AIM-9X, AIM-120, AIM-7F	Directional explosive fuse, helmet- directed targeting, active electronically scanned array	Dual-role missile, miniature air-launched decoy
Missile Defense	National Missile Defense (NMD), modified Aegis missile defense system, airborne laser (ABL) prototype	Mature NMD (kinetic kill), mature ABL, ground-based laser, space-based infrared sensors (SBIRS)	Space-based laser
Naval Strike	Air-launched PGMs (JDAM [joint direct attack munitions], SLAM-ER, JSOW [joint standoff weapon]), Tomahawk Land Attack Missile, advanced digital guidance systems for missiles and projectiles	Land attack standard missile, advanced gun system	Stealthy cruise missile, hypersonic cruise missile, laser, rail
Ground Combat	Hypersonic antitank missile, Longbow Hellfire, guided ATACMS (Army tactical missile system), Javelin, V-22 tilt-rotor aircraft, Comanche networked with other Army systems	Light armored vehicle, lightweight ATACMS (High Mobility Artillery Rocket System--truck-mounted ATACMS), tactical laser, digital battlefield	Netted support to reduce the force “footprint”
Long-Range Strike	B-2, Tomahawk, Terrain Contour Matching, Digital Scene Matching Area Correlation, Global Positioning System	Advanced (stealthy) cruise missile	Hypersonic weapons to reduce response time
Air Strike	Laser-guided bombs, sensor fuzed weapon, long-range precision strike weapons with digital guidance, control, and submunition fuzing	Small diameter Bomb, autonomous air-launched weapon (for example, Low Cost Autonomous Attack Sys-tem), Brilliant Anti-tank Submunition	Directed energy (lasers)
Amphibious Combat	V-22, advanced assault amphibian, mine neutralization	Netted fire support, urban warfare sensors	Quad-rotor vertical/ short tajeoff and landing aircraft
Space Operations	Communications and reconnaissance only	Low Earth orbit antisatellite (ASAT) capabilities	ASAT against geosynchronous satellites
Information War	Organized hacking to gain intelligence or to shut down enemy systems; limited deception	Emphasis on deception to counter netted warfare	Effective information assurance
Command and Control	Link 11, Link 16, and other tactical digital links, plus satellites and digital decision support tools	Direct satellite phones, advanced digital links among large networks of users and sensors, and joint radio	New frequency range for greater bandwidth
Sensors and Reconnaissance	Joint Surveillance Target Attack Radar System, NAVSTAR navigation satellite, GPS, PROPHET (Common platform for Army signals intelligence and electronic attack systems), advanced deployable sonar arrays	SBIRS, Discover II	Space-based air-control radar
Strategic Mobility	Maritime Prepositioning Ships, C-17 transports	High-speed ships	Heavy-lift aircraft offshore base

Table 2. Transformational Technologies (by Military Tasks, ca. 2000).[12]

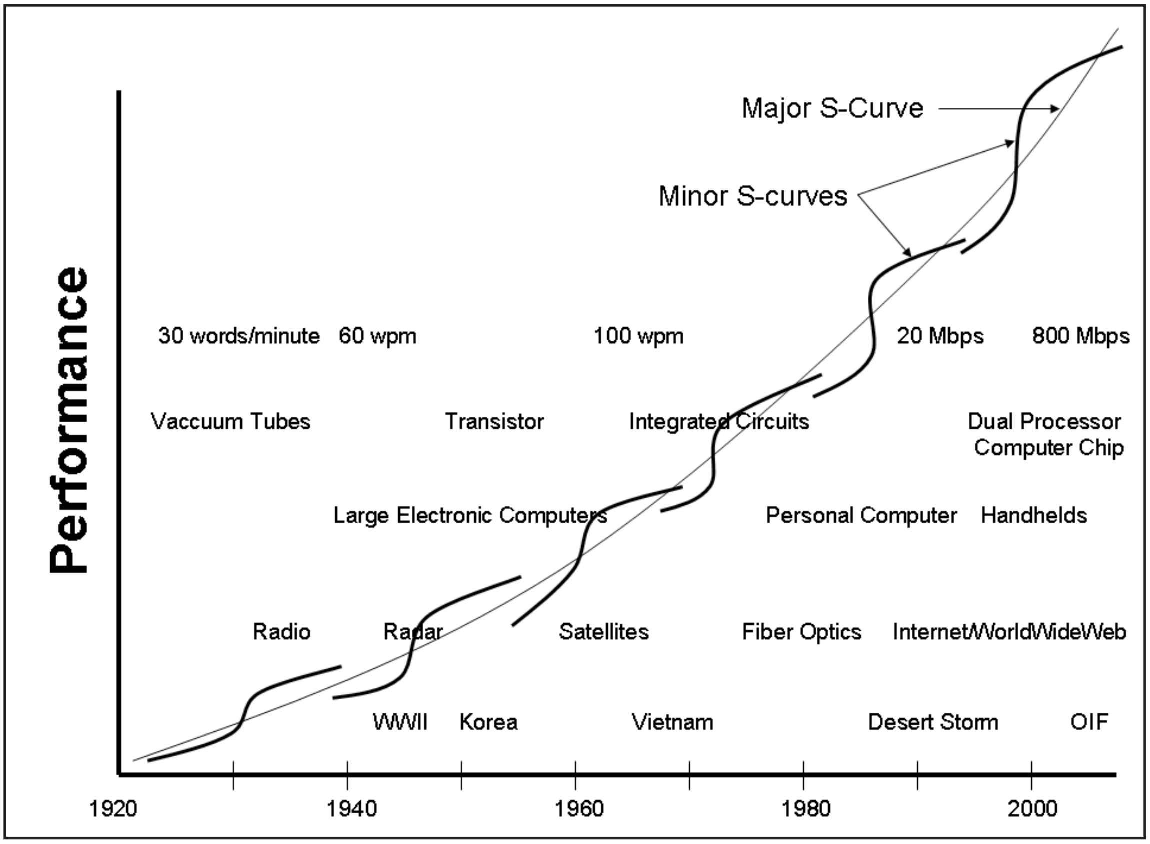


Figure 5. Minor S-curve Contributions to the Major S-curve Representing Performance vs. Time.

also are distinct differences. For one, the rate of technology growth in 1920 was considerably slower than in 2002. This is the result of the exponential growth of the world's body of knowledge, increased capacity for sharing information, Moore's Law, and new technology created by better tools begotten by their immediate predecessors. Secondly, government resourcing for WWII spurred technological growth, whereas, modern technology is principally funded by commercial investment.[10]

Thus, observations over the hundred-year period from 1920 to 2020 show that technology continues to advance at an exponential rate, transformational technologies are paradigm shifts that were not envisioned inside of twenty-year increments, sourcing of investment in technology can alternate between the private sector and government, and war erupts at unpredictable intervals. We can attempt to plot this observation as a series of minor S-curves, which themselves plot a major S-curve with increasing slope as depicted in figure 5. Some useful benchmarks are annotated in the backdrop to that figure.

To date, the slope of both the minor and major S-curves is still increasing and appears to be asymptotic with respect to the y-axis. This means that the rate of progress itself is exponential. The noted inventor Ray Kuzrweil refers to this exponential rate of growth as the Law of Accelerating Returns.[13] He and others argue that, in fact, technological progress will continue to rise until it reaches a point, termed the "Singularity," when man and machine merge. Still others argue that eventually the growth in technological advance must of necessity taper off at a plateau before

the Singularity. It is not the intention of this chapter to postulate whether the major S-curve will continue to accelerate or will begin its maturation and saturation phases. What can be said is that Moore's Law will most likely reach its limit at about 2020, due to the physical limits of feature size on chips. However, given the history of previous minor S-curves, as the saturation point of older technologies is reached, new technological innovations should erupt, creating the demand for increased performance and accelerating expectations still further. What is obvious from history is that new, disruptive technologies are not predictable. Consider the ten years before any of the following innovations: nuclear weapons (1945), transistors (1946), satellites (1958), personal computers (1981), the World Wide Web (1993). Consider that none of us had an e-mail address thirty years ago, had a website address twenty years ago, or foresaw the need for either ten years before we acquired one. Consequently and again, it is irrelevant that Moore's Law will become obsolete because we should expect a paradigm shift when present-day photolithography for making computer chips yields to a new technology. When and if saturation of the major S-curve occurs is only a guess, since we presently have no insight with regard to an innovative technology that will erupt near 2020. Today, that is simply left to science fiction. However, a review of bandwidth growth sheds some light on these S-curve trends.

Bandwidth is a measure of the amount of data transmitted per unit of time. A recent article states,

> *In World War I, the U.S military's communications capability was about 30 words a minute. In War World II, it was about 60. In Vietnam, it was a little over 100. By 2010, it is projected to be 1.5 trillion words per minute flowing around theater. That's the equivalent of the Library of Congress every minute. Buried in there somewhere is the information that a battalion, squadron, component or joint force commander needs.*[14]

To achieve the commanders' needs, the C4 architecture must include next-generation technologies. Many of these technologies are, in fact, envisioned as part of the global information grid (GIG) and the future combat systems (FCS). They are now programmed to be delivered in the 2013 to 2025 timeframe. What can never be predicted is a "disruptive" technology, the World Wide Web in the early 1990s, for example. Disruptive technologies make current architectures obsolete and create paradigm shifts that result in new S-curves. What can be inferred from figure 5 is that paradigm shifts will occur more quickly in the future due to the notion of accelerated returns from the exponential growth of technology. A cursory review of bandwidth growth bears this out. Such growth demands that the life-cycle management of C4 architectures must also shift to the new S-curve paradigm as rapidly as possible. The MSE, fielded in 1990, was a suitable upgrade of communications for the Cold War, but it was virtually "dead on arrival" for Desert Storm and obsolete for OIF. MSE was ten years in development. Developmental cycles of that duration are too long for the predicted frequency of paradigm shifts in the twenty-first century.

Disruptive Technology

"'Disruptive technologies' are those which produce new products in new ways. Initially, they may cost more and be less effective than the more mature, 'sustaining technologies.' But eventually, they become so much cheaper and better as to drive the older technologies out of the market."

The term was coined by Clayton M. Christensen in *The Innovator's Dilemma*.

What then can be said of the methodology for design, development and fielding of C4 architectures? Is the Framework model functional in light of the above? Can its processes be accelerated by technology itself, or is something like the Rubik's Cube a better model for building the C4

architectures of the future? To answer this question, we will examine the pre-OIF C4 architecture in the next chapter and observe it under fire during OIF in the following. Then in light of the present WIN-T program of record originally scheduled to begin delivery in 2008, we will compare it to the ongoing fielding of the JNN in response to post OIF-1 unit rotations. WIN-T fits the Framework model, JNN the Rubik's Cube. The Army's goal is to establish its portion of the GIG (known as LandWarNet) and to field the FCS. Where does C4 architecture end up in 2020, and how does it get there? Is there a way home, do we need to go home, do we want to go home?

Prudens Futuri

3. Pre-OIF C4 Architecture

As you know, you have to go to war with the Army you have, not the Army you want.
—Secretary of Defense Donald Rumsfeld

During a tour of Iraq in 2004, Secretary of Defense Donald Rumsfeld was fielding tough questions about the ongoing War on Terrorism from soldiers at Camp Buehring, Kuwait. In response to a question posed by SPC Thomas Wilson of the 278th Regimental Combat Team, Secretary Rumsfeld's hinted at the battle between legacy systems and the ongoing force transformation undertaken by the United States military. This chapter will establish a baseline of legacy communications systems.

This chapter will examine the Army's C4 communications architecture prior to OIF. The timeframe is March 1995 through January, 2002. Secretary of Defense William Perry's briefing to the United States Senate Arms Services Committee (SASC) in March 1995 marked the inauguration of plans to modernize the current force and recapitalize existing systems. January 2002 marks the start of V Corps' and its subordinate units' planning for possible combat in Southwest Asia.

In January 2003, only two months before the United States attacked into Iraq, a briefing entitled "Fighting Signal in the BCT: C4SIR Architecture" was presented to the Signal Captains Career Course. It stated that the Army's existing switching system was designed to support a bandwidth

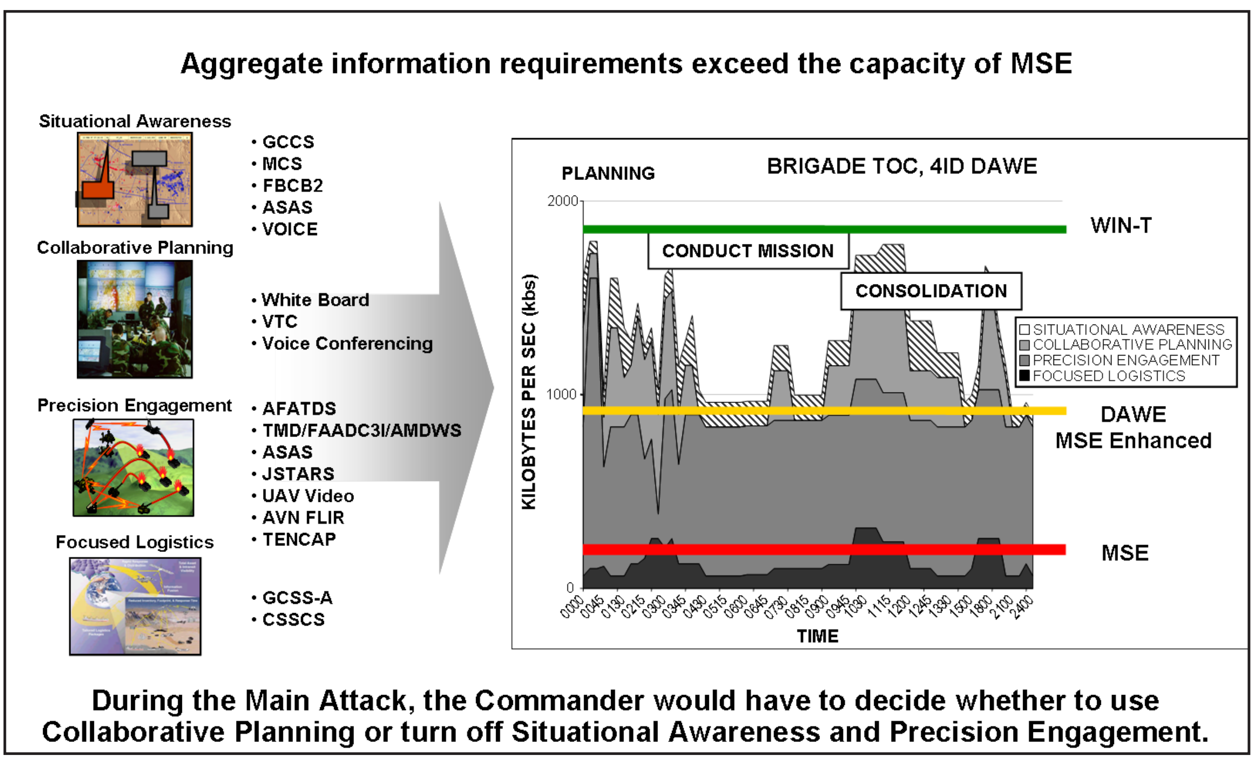


Figure 6. Army Information Requirements.

requirement of 93% voice, 7% data and 0% video. The transmission system, based on terrestrial line-of-site radio vans was limited in the bandwidth that it could support. Its size was based primarily on the voice requirements. It could not, therefore, support the data requirements for combat in future wars such as Iraq. The briefing also pointed out that MSE does not provide the flexibility to "trade-off" between voice and data (see figure 6). In addition, data "pipes" would quickly become saturated, even though voice is under-utilized. As a doctrinal example, the Small Extension Node (SEN) Switch, using the most current upgrade, provides communication services to a division main command post with a maximum data rate of 512 kilobits per second (Kbps). This data rate is split to provide voice, nonsecure internet protocol router network (NIPRNET), and secure internet protocol router network (SIPRNET), along with an automated defense information network (AUTODIN) and a possible video teleconference (VTC) circuit. As a result, the combatant commander must decide whether to use either Collaborative Planning or the Situational Awareness and Precision Engagement tool; he cannot use both simultaneously.[1] This briefing confirmed what many Signal Corps officers already knew or suspected—MSE and even Digital Group Multiplexing (DGM) systems were inadequate for today's modern battlefield and the data expectations of the combatant commanders. As an example of the changes in time, figure 7 shows the growth in data requirements from Operation Desert Storm through operations in Kosovo.[2] This growth in bandwidth requirements continues today.

Over the next ten years, the wording and faces have changed, but the underlying tenets of modernizing the existing force and transforming to a network centric force have not. Secretary Perry articulated his strategy to the SASC:

> *The Department's investment focus must transition to a broad modernization and recapitalization effort. The objective of this effort will be to systematically upgrade and replace portions of the Department's capital stock. It is important to stress that the Department does not need to implement a one-for-one platform replacement of all current inventories. The Department's modernization and recapitalization program will be executed by:*
>
> - *injecting new technologies through service life extension and technological insertions to modernize existing platforms, systems, and supporting infrastructure;*
> - *introducing new systems that substantially upgrade U.S. warfighting capabilities;*
> - *replacing, on a limited basis, older systems on an in-kind basis without seeking to substantially improve or upgrade a given capability.*[3]

From the time of Secretary Perry's briefing, the Army made several major structural moves as it began its transformation. In December 1995, the 4th Infantry Division Mechanized (4 ID) became the Army's first Digitized Division under the Force XXI program. The 4 ID was thoroughly involved in the testing, training, and evaluating of seventy-two major initiatives.

During 1995 and 1996, General William W. Hartzog, Commander, U.S. Army Training and Doctrine Command (TRADOC), brought the serving division and corps commanders together to analyze eleven separate division designs in anticipation of a shift to Army Division XXI. The eleven potential designs were reduced to four. This reduction was primarily based on affordability. The four remaining designs were then modeled and "fought" in simulations in three distinct scenarios, Southwest Asia, Northeast Asia, and Europe.

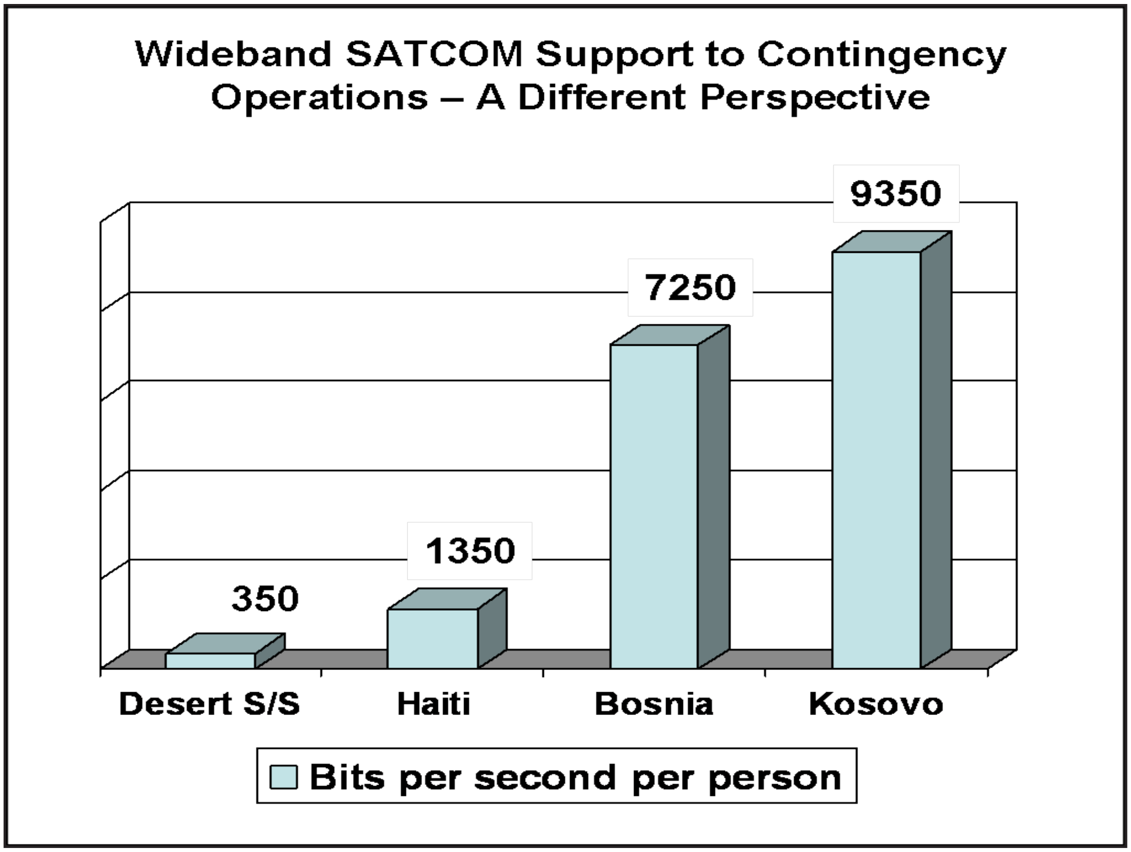


Figure 7. Wideband SATCOM Support to Contingency Operations from Desert Storm to Kosovo

The Army then embarked on a series of Advanced Warfighting Experiments (AWE), culminating with the Task Force AWE held in March 1997 at the National Training Center, Fort Irwin, California, and the Division AWE (DAWE) in November 1997 at Fort Hood, Texas. Following the Task Force AWE, TRADOC considered three variations: the Conservative Heavy Division (CHD), the Strike Division, and the "Brigadist" Division. The CHD was selected based on lethality and affordability, having been thoroughly analyzed during the November DAWE. Based on final analytical data, TRADOC created the Army XXI Division with the assumption that the division was the smallest Army unit that includes elements of all branches and is capable of sustained, independent combat operations.[4]

On October 12, 1999, General Eric Shinseki briefed his plan to transform the United States Army at the Association of the United States Army's (AUSA) annual meeting in Washington D.C. This transformation would create a more responsive, lethal, agile, versatile, survivable, and sustainable force. Without this transformation, the Army would be "stretching yesterday's capabilities to meet tomorrow's requirements [and] would relegate America's sons and daughters, our soldiers, to a tomorrow of increasing uncertainty and risk."[5]

Each of these men spurred the Army's transformation, but the force was still using legacy systems when the United States Army entered Iraq in March 2003. Legacy systems often run on obsolete hardware that requires spare parts that become increasingly difficult and costly to obtain. They are also often difficult to maintain, improve, or expand because there is a general loss of understanding

of the system over time. Despite these problems, organizations, to include the Army, can have compelling reasons for keeping a legacy system:

- The costs of redesign may be prohibitive.
- The system requires close to 100% availability, so it cannot easily be replaced.
- The user expects that the system can easily be replaced when necessary.
- The system works well enough that the owner sees no reason for changing it.
- A new system would have a prohibitive operator personal cost in money for training and in lost man hours.

New technologies, when properly injected into an organization's legacy systems, can provide a significant benefit to the unit. The flyaway Tri-Band Satellite Terminal, which was introduced to the Army prior to OIF, is one example. It provided units with a Commercial off the Shelf (COTS) satellite system capable of supporting a variety of missions while fully compatible with the existing ground mobile forces (GMF) satellite terminals. Such new technologies provide a number of significant benefits, including reduced cost, faster procurement, ease of employment, and a smaller size than similar systems developed through the standard acquisition process. The users are insulated from the inefficiencies of their legacy systems while moving towards increased capabilities found in newer technology.

Some of the thorniest problems that units face spring from the effort to leverage or replace existing systems while maintaining combat effectiveness. An example of this occurred during Operation Desert Storm with the 141st Signal Battalion. In 1990, the 141st was under the command of LTC Donald E. Fowler II. They were scheduled to undergo MSE modernization fielding from November 1990 to May 1991. For the months prior to receiving deployment orders for Desert Storm, the unit was focused on turning in the older, Tri-service Tactical Communications System (TRI-TAC) generation of communication equipment. When the deployment announcement for Desert Storm was made, the 141st did not have any equipment in the motor pool with which to deploy. The decision was made to halt the unit's MSE modernization program and to retrieve its older generation TRI-TAC equipment in order to deploy with the 1st Armor Division (1 AD). Once in the Persian Gulf region, the 141st was forced, due to lack of personnel and equipment, to modify signal doctrine and use a radically modified communications network in order to provide support to the 1 AD during Operation Desert Storm.[6]

Following the warfighting experiments in 1997, the Combined Arms Center submitted its Capstone Requirements Document on 30 June 1999, providing "guidance for the development of the Operational Requirements Documents (ORD) for all current and future Army Command, Control and Communications (C3) Systems."[7] The Capstone Requirements Document stressed three key central components that all new systems were to incorporate. These systems were Soldier-System Interface (SSI), which described personnel and common/look/feel requirements; the TOC, which described requirements for integrated, digitized TOCs; and the Capabilities Required Annex. The digitized TOC included an updated version of the Army Battlefield Control System (ABCS), Revision 1b.

Over time, with the addition of "computers" to the mix, C3 became C4. C4 is the integration of doctrine, procedures, organizational structures, personnel, equipment, facilities, communications, and intelligence to support a commander's ability to command and control across the range of military operations. C4 provides commanders with timely and accurate data and systems to plan,

monitor, direct, control, and report operations. Efficient C4 is the foundation and the enabler for all other operations. It provides system interoperability, near-real-time collaborative planning, and the shared situational awareness necessary to effectively synchronize combat arms operations.

Organizational Structures

A look into the legacy systems of the Army reveals that they were not able to interoperate at all times. A lack of interoperability was a recurring problem. Sometimes the problems were caused by the unit's position in the new equipment fielding process; sometimes they were caused by the version of system software that the unit had received. These problems are frequently highlighted throughout Volume 1 of this case study, as they illustrated the differences in capability for the haves and have-nots.

Unlike systems interoperability, the TOE is a document that prescribes the wartime mission, capabilities, organizational structure, and mission essential personnel and equipment requirements for military units. It portrays the doctrinal modernization path of a unit over time from the least modernized configuration (base TOE) to the most modernized (objective TOE).

The Base Table of Organization and Equipment (BTOE) is an organization design based on doctrine and equipment currently available. It is the lowest common denominator of modernization and identifies the mission essential wartime requirements for personnel and equipment based on equipment common to all units of a given type organization. In the development of the TOE, the Objective Table of Organization and Equipment, or OTOE, as defined in AR 71-32, is a fully modernized, doctrinally sound organizational design that sets the goal for planning and programming of the Army's force structure and supporting acquisition systems, primarily in the last year of the program objective memorandum and the extended planning annex.

A Modified Table of Organization and Equipment (MTOE) is an authorization document that prescribes the modification of a basic TOE necessary to adapt it to the needs of a specific unit or type of unit.

Each TOE is identified by a unique number that should remain the same throughout the life of the organization. TOE developers, in coordination with the TRADOC force designers, are responsible for developing the proposed TOE number.[8]

As mentioned in Volume 1, preparations for combat in Iraq for V Corps and the 3rd Infantry Division (Mechanized) began well over a year in advance of 20 March 2003, the kick off of the ground war in Iraq. The intensity of training, planning, preparations, mobilizations, and deployments throughout the military, and the improvements in military capabilities during the twelve years since Desert Storm set the conditions for the Operation Iraqi Freedom offensive.

Between 2001 and combat actions in Iraq during 2003, the V Corps Deputy Chief of Staff, COL Thomas A. Kruegler, was tasked to develop the command and control redesign for V Corps, based on the DTLOMS model (figure 8).

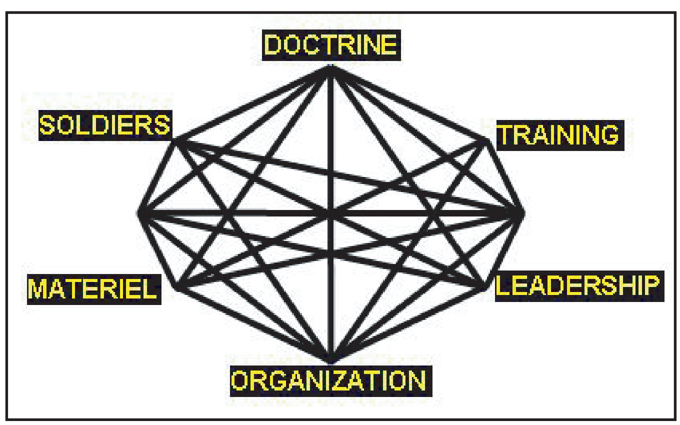


Figure 8. V Corps DTLOMS Model

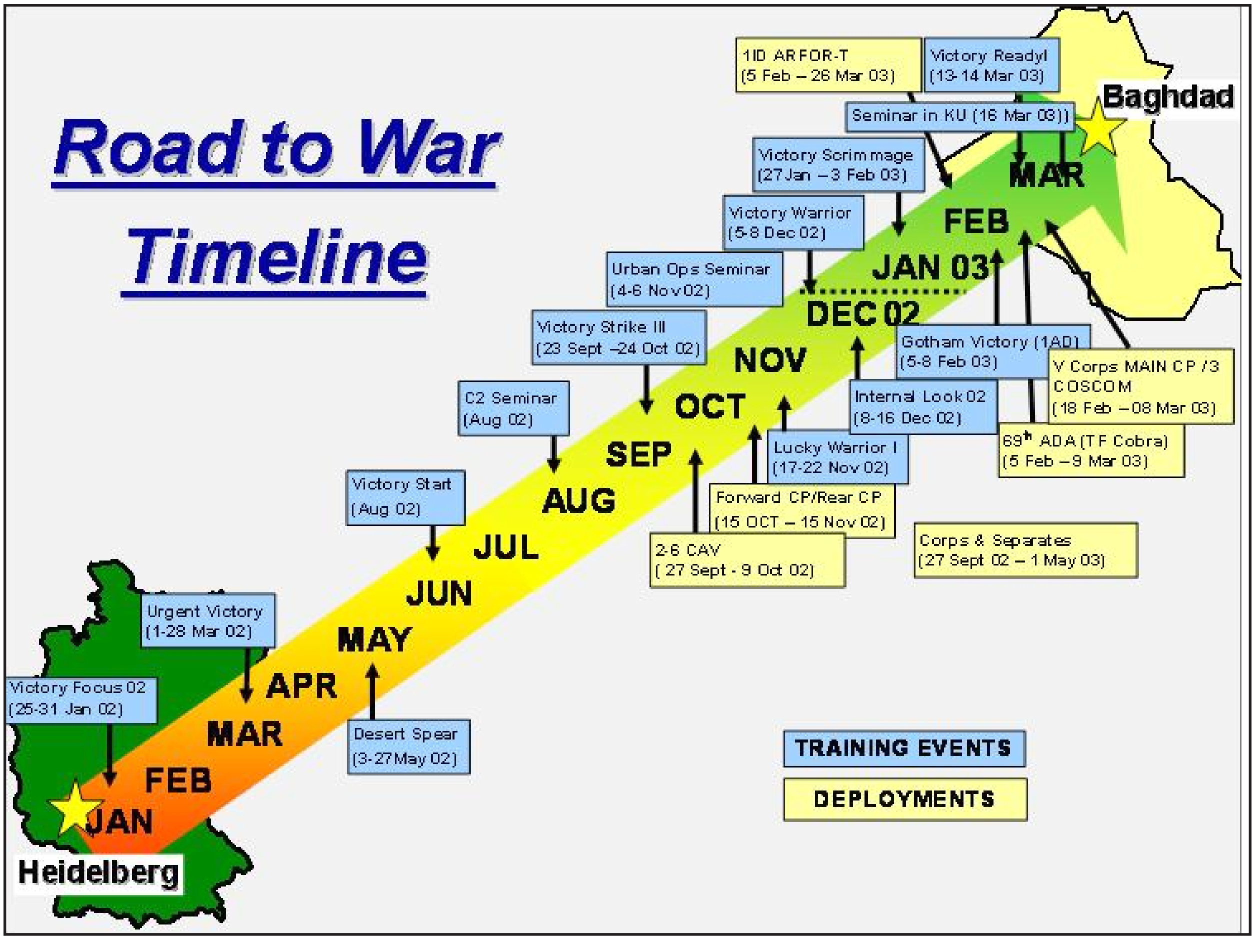


Figure 9. V Corps Road to War Timeline

The V Corps redesign addressed six independent axes: physical plant, battlefield visualization, communications and digitization, common operating picture (COP) and battlefield visualization, home station bed down, and tactical and strategic transportation.

Numerous exercises were designed to test and rehearse deployment plans and reception, staging, onward movement, and integration (RSO&I) procedures. They also included tactical maneuver plans, coordination procedures, and standardized information system displays and requirements. Through exercises, seminars, and rehearsals (as shown in figure 9), V Corps was able to shift its USEUCOM theater focus to the USCENTCOM area of responsibility, where it had not previously operated.

The tasks for V Corps were monumental. Not only did they have to ensure that all subordinate commands (those coming from Germany as well as those coming from CONUS) would be able to communicate with the Corps headquarters, but that they would be operating off of a common version of software within ABCS and within systems not included in the ABCS, such as command and control personal computer (C2PC).

Part of this training and exercising was to ensure that those working with information systems would be fully able to understand and leverage the systems to exploit all available information.

Some systems were not provided until units arrived in Kuwait. This limited the ability to fully train on new systems and hampered the development of tactics, techniques, and procedures (TTPs), which normally would have resulted from training, exercises, and rehearsals.

Out of these and other tests, initiatives were developed into the programs that were used during Operation Iraqi Freedom. These initiatives combined legacy systems, COTS systems, and items being designed for the military from agencies such as DARPA. Other programs that were implemented after the combat phase will be discussed in later chapters of this volume.

Mobile Subscriber Equipment

The legacy communications architecture that V Corps and 3ID took to war during OIF was based on two major systems—MSE and DGM. These systems were developed during the Cold War and did not support an OIF-style battle. During OIF, V Corps and its subordinate units conducted the longest and fastest armored assault in the history of warfare, thrusting from the Kuwaiti border into the center of Baghdad, a straight-line distance of 540 kilometers.

In 1979, the Joint Operational Requirement Board approved the development of the MSE system using the non-developmental item (NDI) acquisition approach. This approach was directed by the Under Secretary of the Army in 1983. The first unit was equipped by 1988, and the last unit completed in 1993.

Since MSE was an NDI program, multiple sources of COTS equipment were utilized in its fielding. This method of acquisition is still in use in the development of several current communications based programs that will be discussed later, such as the JNN and the Deployable Ku Band satellite system known as a DKAT. These programs can, at times, compete with the long-term development of systems funded as programs of record, as both battle for finite pool of funds to develop their products.

MSE has been the communication standard for almost two decades and will continue to be the communication standard until replaced by anticipated programs of record like WIN-T or the COTS-based Joint Network Node (JNN).[9] It has been a consistently reliable program when used in a relatively static location or training environment. In a doctrinal setting, MSE is a common-user, switched communications system of linked switching nodes in Army forces at echelons corps and below. These nodes form a grid that provides the force with an area common-user system, combat net radio, and the Enhanced Position Location Reporting System (EPLRS). This system also allows for the rapid movement of mobile subscriber radiotelephone terminal (MSRT) users if they are within the established grid (see figure 10).

Rules Governing NDI

1. Any item available in the commercial marketplace.
2. Any previously developed item in use by a Federal, State, or local agency of the United States or a foreign government which the United States has a mutual defense cooperation agreement.
3. Any item described in sub-paragraph 1 or 2 above that requires only minor modification to meet requirements of the procuring agency.
4. Any item being produced that does not meet the requirements of subparagraphs 1, 2, or 3 above, solely because the item is not yet in use or is not yet available in the commercial marketplace.

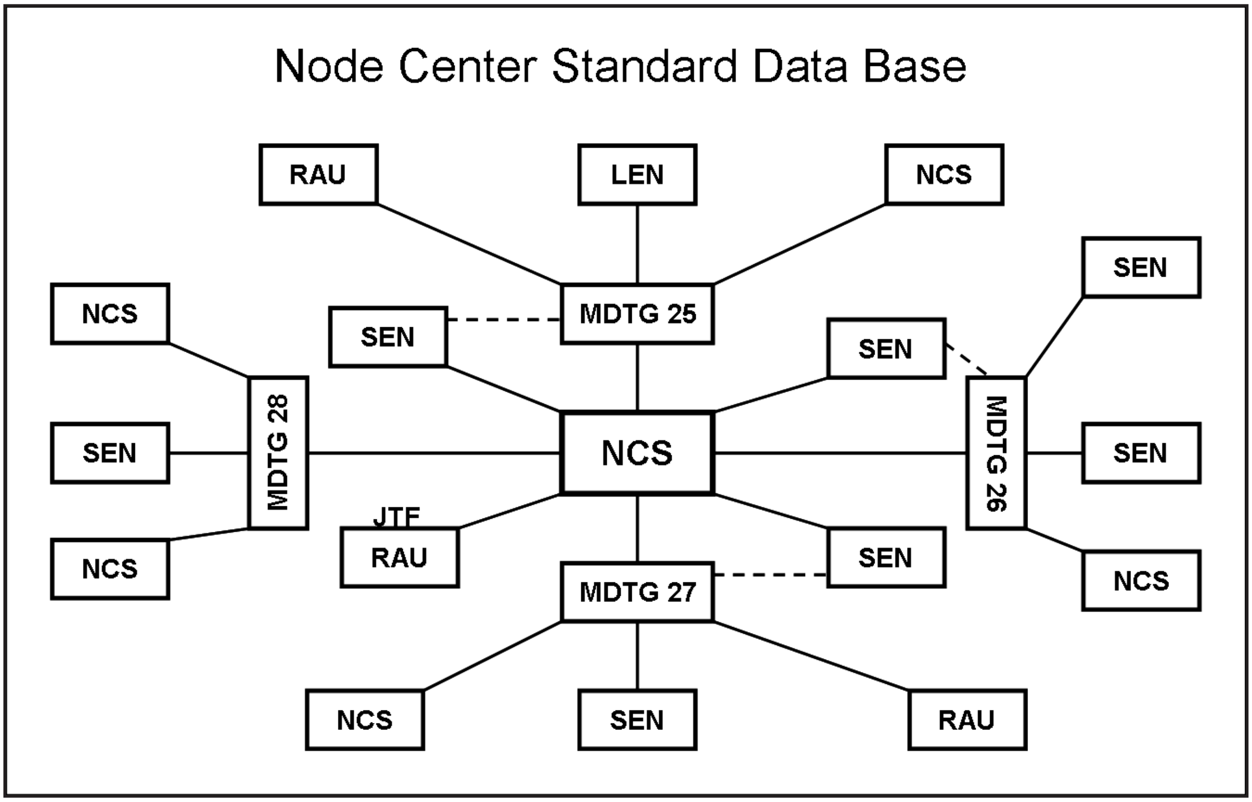


Figure 10. FM 11-43 Node Center Standard Database

As the 3 ID moved towards Baghdad, this grid was never developed. The dispersion of forces, the speed of the maneuver units and threats of weapons of mass destruction did not afford units the time necessary to establish a robust and reliable mesh network. With time and distance being a constant factor in communication support, these units reverted to a series of point-to-point and hub-spoke network designs as depicted in figure 11. These networks increasingly relied on space-based communications links to support the various command centers during the drive to Baghdad. The 123rd Signal Battalion, the signal battalion organic to the 3 ID, was equipped with only two AN/TSC-85 and three AN/TSC-93 satellite systems.

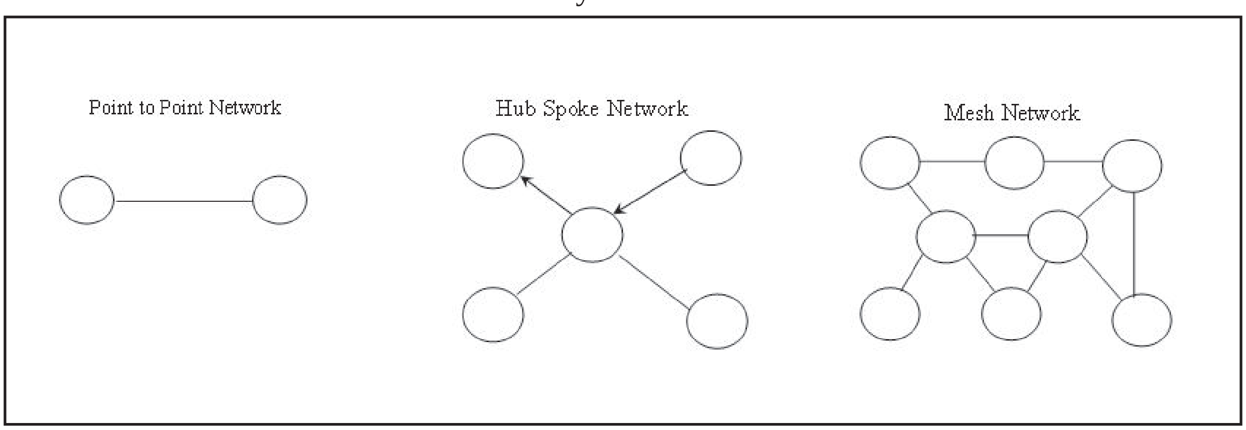
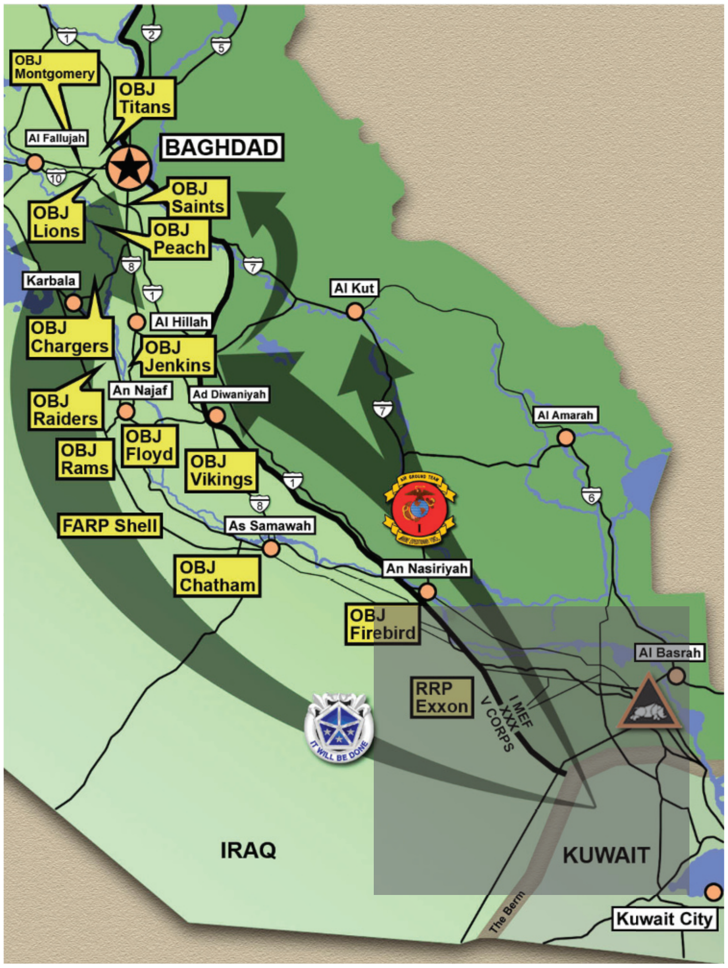


Figure 11. 93rd Signal Brigade TACSOP: Standard Networks



This box approximates the size of a fully established corps MSE network of 15,000 square miles.

Figure 12. V Corps: Road to Baghdad

MSE was developed to support a corps of five divisions in an area of operations (AO) up to 15,000 square miles, or nearly 24,300 square kilometers. A standard divisional signal battalion is able to field an MSE grid consisting of four to six node centers (NCs) that make up the backbone of the network needed to develop a robust mesh diagram. Throughout the maneuver area, subscribers connect to the small extension nodes/large extension nodes (SENs/LENs) by radio or wire. These extension nodes serve as local call-switching centers and provide access to the network by connecting to the node center switch at the NC. A fully developed MSE network would not be able to support V Corps and 3ID throughout their march to Baghdad (see figure 12). Even without additional assets, the battlefield that faced 3 ID was much too large and, particularly, far too long to be doctrinally supportable. Without additional tactical satellite (TACSAT) assets, the 3ID would barely have been able to establish communications from the Coalition Forces Land Component Command (CFLCC) headquarters at Camp Doha, Kuwait, to the Iraqi City of an-Nasiriyah, far less than half the way to Baghdad.

During OIF, the 22nd Signal Brigade and the 123rd Signal Battalion were the major signal units associated with V Corps and 3 ID. The 22nd Signal Brigade was under the command of COL Jeffrey Smith, while the 123rd was under the command of LTC Joseph Brendler. Their units provided the bulk of communications support to V Corps and 3 ID during the combat phase of OIF.

The standard corps signal brigade is responsible for the installation, operation, and maintenance of the MSE corps communications system. COL Smith and the 22nd Signal Brigade provided area communications support to the corps main, jump, tactical, support commands, and rear command posts. The corps signal brigade is also charged to provide support to major subordinate commands of the corps and to provide a corps special staff for technical communications, automation, and communication security assistance to the corps.

The 22nd Signal Brigade was responsible on a twenty-four-hour basis for the planning, engineering, and controlling of the corps communication system. The standard corps signal brigade is defined in FM-11-30, *MSE Corps/Division Signal Unit Operations,* with the TOE shown in figure 13. It is responsible for the management, technical control, and planning of the MSE Network through the use of the following TOE systems, which are discussed along with the communications capability of a standard TOE corps signal brigade in Annex C:

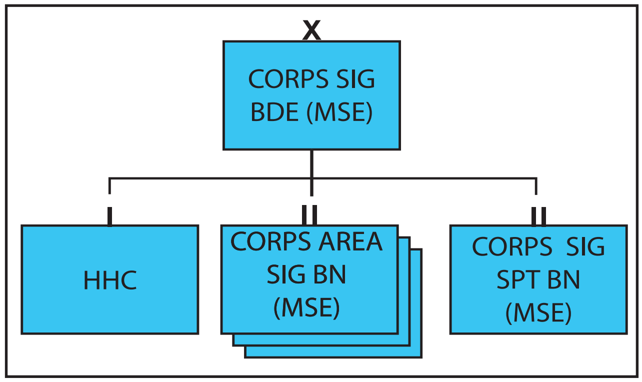


Figure 13. FM 11-30: TOE for a Corps Signal Brigade

- 22 Node Centers
- 4 Large Extension Node Switches
- 144 Small Extension Node Switches
- 47 Radio Access Units to provide access for MSRT subscribers
- 261 Line-Of-Sight (LOS) Radios
- 4 LOS Radios and four wire NATO interface units
- 6 tactical satellite multichannel terminals

The corps signal brigade is also charged with support to major subordinate commands and provides special staff for technical communications, automation, and communication security assistance to the division.

The standard division signal battalion is responsible for the installation, operation and maintenance of the division's MSE communications system. The 123rd Signal Battalion provided area communications support to the division main, jump, tactical, support commands, and rear command posts. The 123rd Signal Battalion was responsible on a twenty-four-hour basis for the planning, engineering, and controlling of the divisional communication system. The standard division signal battalion is defined in FM-11-30, *MSE Corps/Division Signal Unit Operations,* as shown in figure 14.

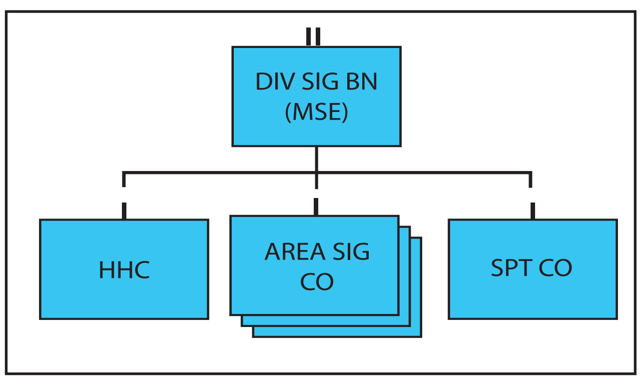


Figure 14. TOE for a Division Signal Battalion

Digital Group Multiplexing—Echelon Above Corps

Digital Group Multiplexing communications systems are found primarily at Echelon Above Corps (EAC) signal brigades. These units are responsible for theater area communications and use a mix of MSE and DGM systems.

The digital systems found in EAC units, as well as the emerging communications programs such as the Army Battle Command Systems, have greatly enhanced the commander's battlefield situational awareness and COP. Digital systems are cheaper, easier to encrypt, have better error correction techniques, and faithfully regenerate digital signals. DGM systems are composed of three major groups: switches, line-of-site radio assemblages, and beyond line of site systems.

During Operation Desert Storm, DGM units used the AN/TTC-39D as their primary switch. By OIF, the AN/TTC-39D (figure 15) had been replaced in most units by the SSS or Single Shelter Switch (AN/TTC-56) (figure 16). Both switches are capable of interfacing with EAC and MSE systems. While the 39D was able to support more links, it requires a 5-Ton vehicle, which makes it much larger and more difficult to transport than the smaller SSS. The SSS is C-130 transportable, while the 39D requires at least a C-17 airframe.

Figure 15. AN/TTC-39D

Figure 16. AN/TTC-56 SSS

The 39D and SSS are fully redundant Common Baseline Circuit Switches (CBCS) that run an active reserve database that monitors every action of the primary database. In the event of a major switch failure, the operator can revert to the active reserve, which will minimize—to the point of transparency—the impact of system failure on direct customer support. This is not an option in the MSE switches, as they are non-redundant.

Army Battle Command Systems

The Army Battle Command Systems, or ABCS, is an integrated family of command and control systems designed for the command and control of battlefield operating systems. ABCS joins together multiple programs responsible for the integration of digital and electronic systems that provide information to the warfighter in the joint environment.

From the Combined Arms Center Capstone Requirement and General Shinseki's transformation briefing afterwards, the ABCS program was integrated into the 4 ID under the Force XXI program in 1995. The 4 ID tested the ABCS from the Brigade AWE in March 1997 through the Division AWE in December 1998. The purpose of the AWEs was to assess the enhancements to warfighting achieved through digitization. Based on the AWEs' initial success, the Army began to fully

transform the 4 ID into the first digitized division with the requisite equipment, computer software, doctrine, tactics, techniques, and procedures, training materials, and instruction.

ABCS components are designed to interoperate with the other Department of Defense command and control systems. The ABCS has eight primary components:

- Advanced Field Artillery Tactical Data System (AFATDS)
- Air and Missile Defense Planning and Control System (AMDPCS)
- All Source Analysis System (ASAS)
- Combat Service Support Control System (CSSCS)
- Force XXI Battle Command - Brigade and Below (FBCB2) System
- Global Command and Control System-Army (GCCS-A)
- Maneuver Control System (MCS)
- Tactical Airspace Information System (TAIS)

One of the major enhancements to combat power provided by ABCS is the ability to provide a clear, accurate, and common view of the battlespace. This common view is the common operational picture, or COP. The COP enables the combatant commander to digitally establish and share his combat point of view through a variety of visual products for COP users. It enables a shared situational awareness that significantly improves the ability of commanders at all levels to quickly make decisions, synchronize forces and fires, and increase the operational tempo. The COP consists of shared information on friendly and enemy forces, operational graphics, and other

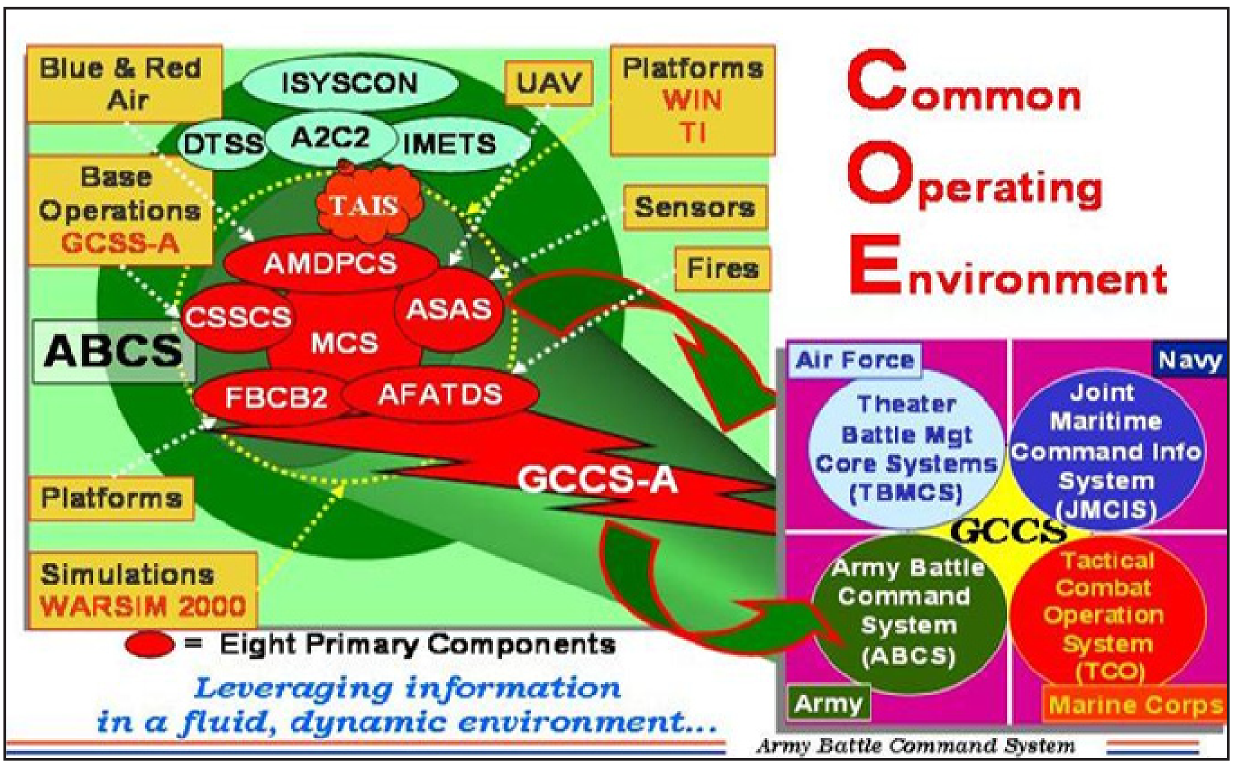


Figure 17. Eight Primary Proposed Army Battle Command Systems

combat-enabling information such as terrain and weather data. The COP lets the commander tailor and filter information and monitor current operations and serves as the basis for planning future operations. The data can then be shared through collaborative tools to meet the requirements of like-equipped units.

The COP application is available on ABCS computers and supporting systems for digitized units. The COP application displays information from a shared database, the Joint Common Database (JCDB). This information can be quickly accessed while displaying on one screen in the command post the critical, time-sensitive information, intelligence, and data drawn from the other Battlefield Functional Areas (BFAs) and from higher and lower systems. The COP is dynamically updated. As data changes in the JCDB, the COP reflects those changes in near-real-time.

The COP template includes the following:

- Notional Overlays
- Friendly unit locations
- Specific vehicle locations
- Graphic control measures
- Other enemy unit locations
- Specific enemy equipment, facilities and individuals
- Logistical information
- Adjacent and higher units
- Unmanned aerial vehicle (UAV) activity
- Cruise missile speed and direction of flight
- Current weather conditions, weather forecasts, and severe weather warnings
- Mobility, trafficability and line of sight decision aids

Prudens Futuri

4. C4 Architecture during OIF 1

Don't underestimate the ability of our signal soldiers to accept and embrace commercial technology. Don't worry about it. Our kids are smart, they're innovative, they're bright, they're inquisitive—they'll figure it out…and did.

—LTG William S. Wallace

Between 19 March and 1 May, 2003 V Corps conducted the longest and fastest armored assault in the history of warfare, attacking from the Kuwaiti border into the center of Baghdad, a straight-line distance of 540 kilometers.

> *Victory Corps and the First Marine Expeditionary Corps overwhelmed the Iraqi foe in 21 days of fierce fighting characterized by classic small unit firefights, Meeting Engagements, Raids, Feints, Brigade-sized shifts in Task Organization, Divisional-level exploitation, rapid changes to unit mission, synchronized seizure of cities along the tactical Lines of Communications. Those operations were conducted over a battlefield as deep and wide as the state of California, and an area that was non-contiguous, even within brigade sectors. The network encountered steep escarpments and mountains that effectively divided the battlefield, severe heat that periodically overwhelmed the network's environmental protection capability, contrary winds that altered transmission azimuths and sprawling urban structures that precluded Line of Sight architectures. 3 ID's seizure of Baghdad culminated 600 kms of fierce meeting engagements executed under conditions of furious maneuver.*[1]

The V Corps' lines of communications ultimately spanned a distance equivalent to that from the Normandy beaches to the Rhine River, which V Corps had spanned between June and late September of 1944.[2]

V Corps and the 3rd Infantry Division (Mechanized) (3 ID) successfully communicated over non-doctrinal distances while on the move during OIF. They communicated not only by using legacy radio and satellite systems—existing doctrinal procedures—but also by procuring and integrating new COTS equipment. With the addition of COTS equipment, V Corps and its subordinate units developed a series of tactics, techniques, and procedures (TTPs) to resolve issues that arose during planning for OIF.[3] These TTPs were developed in a series of exercises beginning with Victory Focus, in January 2002, up to Victory Ready, in March of 2003.

OIF was the first true example of a modern military force using NCW. OIF was inherently a tactical-level fight. It was characterized by mobile, widely dispersed forces, a high operational tempo and simultaneous execution on a very fluid and non-linear battlefield. Actions among the joint, operational, tactical and interagency organizations required heightened levels of collaboration and coordination in order to execute the V Corps' battle plan.

More so than at the operational level, the tactical level required C4 technologies that were untethered from fixed architectures, an uncommon attribute among legacy C4 communication systems. The tactical level posed the greatest C4 challenges. During the maneuver phase of the

war, the Operational Commands' network of choice was the Defense Information Systems Network (DISN), while V Corps relied on the three tactical network generations of TRI-TAC DGM, MSE, and FORCE XXI systems. The resultant network required units from every active duty corps signal brigade and three of the four active duty theater signal brigades.

With the volume of units in a limited electomagnetic operating environment, spectrum management was a major concern at all levels. Spectrum management ensures electromagnetic compatibility and frequency supportability of all known systems. This includes, but is not limited to, weapon/radar systems, electronic requirements, frequency assignment, electromagnetic interference resolution, electronic warfare de-confliction, multinational forces (MNF) frequency production, and radio frequency net requirements.

The combined task force (CTF) C6, COL Jeff Smith, was responsible for the establishment and management of the electronic frequency spectrum across the CTF. To accomplish these tasks, he coordinated directly with the host nation and with allied frequency management authorities. In the case of an attacking force or when no effective host-nation government exists, the C6 is responsible for frequency management. By establishing proper spectrum management, the C6 or his delegate helps to prevent "electronic fratricide."

Prior to OIF, the CENTCOM J6, in conjunction with MNF forces, established a spectrum management team. This team was stood up prior to actions in Iraq to ensure frequency supportability, compatibility, and friendly force control of the electromagnetic space prior to deployment of forces. Major General Moran noted that his biggest problem with spectrum management resulted from the decision to bring 4 ID into Iraq.

Spectrum Management

The planning, coordinating, and managing operational, engineering, and administrative procedures, with the objective of enabling electronic systems to perform their functions in the intended environment without causing or suffering unacceptable interference. (JP 1-02).

> *Where it became a concern [was] when we were going to introduce 4 ID through Kuwait into Iraq…Frequency management was probably the biggest concern that we had. The fact that we had to rethink, redo and re-look our whole spectrum management plan was probably the greatest outcome. We were less concerned about that [frequency management] when 4 ID was going to be operating up in northern Iraq…physically separated, but when all of the sudden they were going to come all the way through the V Corp rear and the MEF rear and then get up into [Iraq]… frequency management was our biggest concern. Fortunately, we had the time. From the time the decision was made [to bring 4th ID into Iraq through Kuwait]…we had a couple of weeks to make the appropriate adjustments and then to get those changes articulated and then implemented down into the lower formations.*[4]

The legacy network found within U.S. and coalition forces during OIF was based on the MSE and DGM systems mentioned in Chapter 3. MSE was fielded to the force around the time of Desert Shield and Desert Storm, and it had done exactly what it was advertised to do. It provided fixed command posts with reliable intra-corps voice and data through the use of tactical, high-speed data networks (THSDN) to distribute SIPR, NIPR, and information systems.

During OIF, MSE provided tactical voice communications to over one hundred cross-line-of-departure fixed command posts within five days of the war's initiation, and 270 by the conclusion of the maneuver phase of the war. With all of these MSE and DGM switches in the network, the

corps commander could call any one of his subordinate commanders on virtually every day of the war. This was achieved not only through the use of terrestrial radio communication but also with space-based communication platforms such as the Multi-Channel (MC) and Single Channel (SC) Tactical Satelite TACSAT) systems.

Even with supporting the 270 separate command posts, MSE and DGM were not sufficient for OIF. According to COL William Pope, then director of the V Corps Network Operations and Security Center, "it's not what MSE did, though, that matters. It's what it's not. It isn't DISN. It's not satellite-based. It's not lean, and integrated. It's not agile. It's not robust. It can't keep up."[5] Even though many of the MSE and DGM nodes were supported by satellite-based systems, the non-satellite supported switches were found to be inadequate for the modern battlefield. The Army had failed to fully act on the lessons learned from Desert Shield and Desert Storm and update the communication platforms for mobile operations.[6] Additionally, it had failed to provide the force with a communications system that was able to support the combatant commander with time-sensitive situational awareness (SA) and battle command on the move (BCOTM) capabilities. During an interview in Baghdad, LTG Wallace noted that "the fact is, we're probably not as far along as we should have been, knowing where we were four to five years ago when I was in command of the division [4 ID]."[7]

As the commanders' expectations have increased so have the data requirements to be supported by signal battalions. MSE was expected to effectively distribute these requirements, even though a WIN-T briefing from 1998 (shown in figure 20 of Chapter 5) had illustrated how divisional signal units would be unable to support the ever-growing demands of the modern military force. To further illustrate this point, the DISA Director, Lieutenant General Harry Raduege, in a briefing to the National Defense Industrial Association in February of 2004, confirmed that data requirements per individual soldier had risen over one hundred percent since Desert Storm, as illustrated in figure 18.[8]

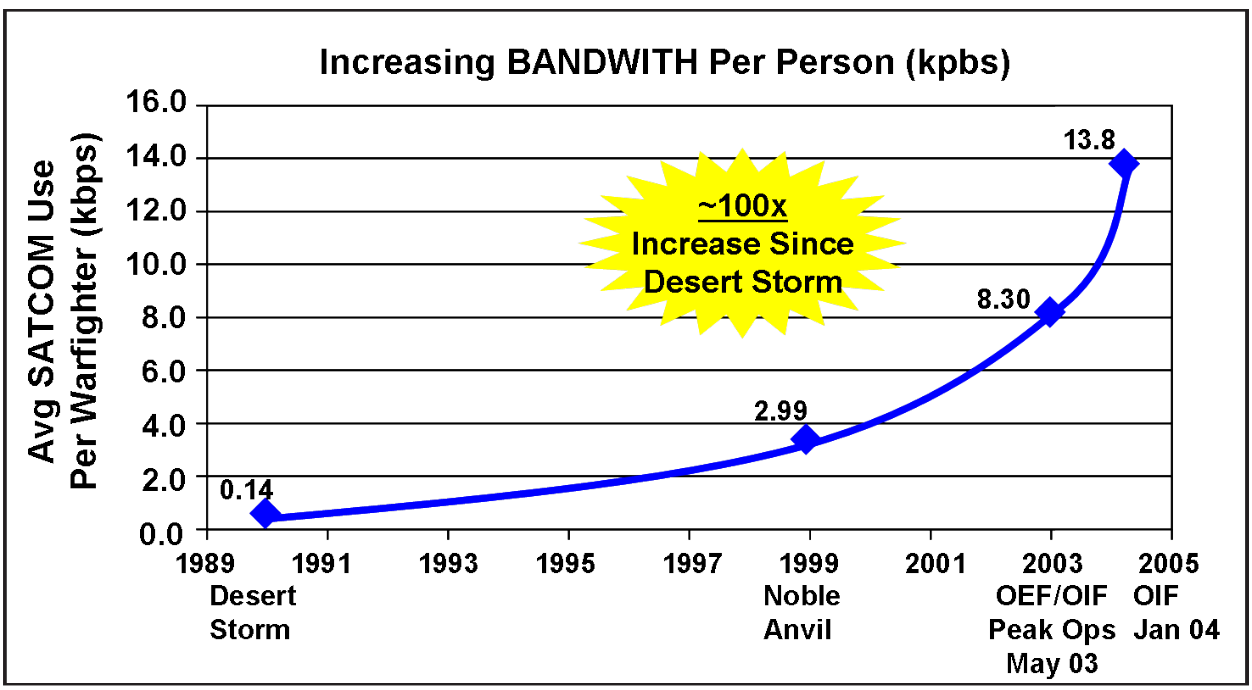


Figure 18. Increasing Bandwidth per Person from Desert Storm to OIF

During the war, eleven command posts were established using satellite-based range extension assets to connect into and derive services from an already established MSE corps tactical network. Installation varied from forty-five to sixty minutes for initial operating capability, which did not include full functionality for the entire command post. These CPs received MSE voice, SIPR, NIPR, and DSN, but they did not receive VTC or Defense Red Phone Switch (DRSN) connectivity. Range Extension equipment included military multi-channel TACSAT assets based on the legacy AN/TSC-93, AN/TSC-85, and the AN/TSC-154 SMART-T. Divisional Wideband Belts provided access to the Brigade Combat Teams (BCT), but their success was predicated on the ability of the division to move its network in the midst of a fast-moving fight.

These eleven command posts enjoyed full MSE services and selected information systems services. Those capabilities required the installation of an in-theater, MSE general support network to serve as a base into which SEN and LEN switches connected. The scarcity of MSE ports and tactical satellites limited the number of CPs that could be supported to eleven: the V Corps TAC, the attack aviation regiment, one of two corps' artillery brigades, the divisional cavalry squadron, and major divisional CPs.

LTG Wallace's C2V was outfitted with an embedded Command Post Module. This was an integrated system of commercial technologies that provided wideband capabilities and received DISN services directly from a DISN tactical switch. Within twenty minutes of arrival, the corps' commander had full DISN services as well as MSE connectivity. He was the only commander on the battlefield who enjoyed this capability. LTG Wallace's C2V quick halt capabilities never failed, enabling full DISN and internal corps MSE communications. His international maritime satellite (INMARSAT)-based SIPR feed was refreshed continuously, providing him SA and SIPR exchange even when his connection to the wideband DISN network was inactive. His Global Broadcasting Service (GBS) receive suite provided real-time continuous video from the UAV. The V Corps commander's C2V was the most effective, efficient command post of its size in the war. And it needed to be; in LTG Wallace's own words, "the requirements for direct DSN, NIPR, SIPR, [GBS/UAV] connectivity are as great for the tactical force as they are for the operational force, and you better understand that."[9]

The major C2 voice systems of CFLCC, CENTCOM, and DoD were secure DSN and DRSN. Neither was effectively extended forward of the Corps CPs in Kuwait. DRSN was available only via Joint Node at Corps Main. Logistics needs were supported through the MSE network by tunneling[10] unclassified messages through the classified network using a TACLANE[11] encryption device. Even with this workaround, the MSE network was insufficient for the support of the logistical, medical, or administrative operations, commonly known as the Standard Army Management Information System, or STAMIS.

As the need for better BCOTM became a validated requirement, V Corps and 3 ID developed smaller, more mobile CPs that included the M4 C2Vs. The C2Vs were equipped with a tailored communications package that included FM, HF, EPLRS, and TACSAT radios, Iridium phones, FBCB2-BFT, an INMARSAT data connection, and external connections for more robust data and phone connectivity via MSE at the halt. The SC TACSAT, FBCB2, and Iridium provided a minimal C2 on-the-move capability, but the INMARSAT data connection was either not used or was used so infrequently that it was of marginal value. Additionally, the INMARSAT radios were being fielded to the 3 ID up to the date the division crossed into Iraq, and they were not fully functional until after the lead elements reached attack positions north of An Najaf, around 3 April 2003.

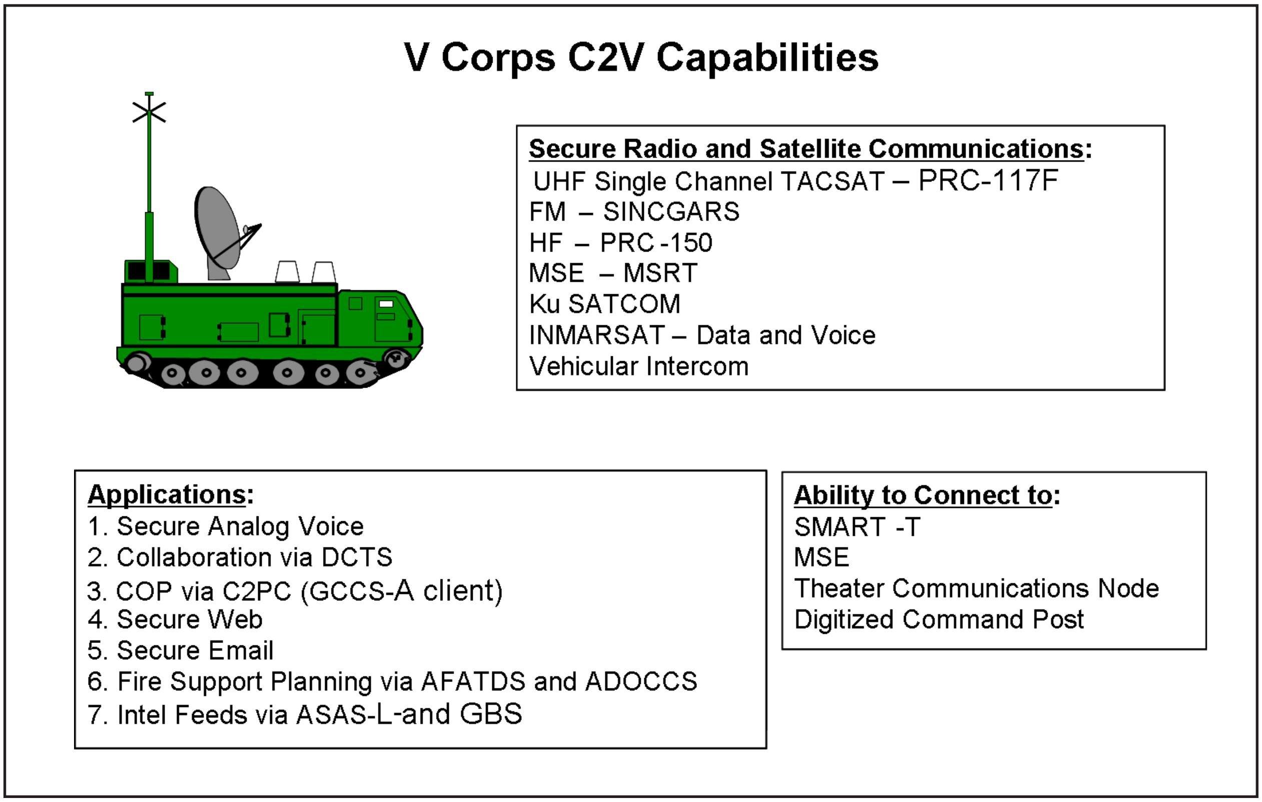


Figure 19. V Corps C2V Capabilities

Additional COTS systems in the network architecture for the C2V were commercial satellite systems, routers, servers, a voice over IP (VOIP) switch interface unit, and a PROMINA[12] multiplexer to break out the voice, data, and video messages. These systems enabled the commander to connect with SMART-T, MSE, DGM, theater communications nodes, and digitized command posts. The integration of these COTS systems and the legacy systems provided the corps' commander with on-the-move communications across the battlefield. Figure 19 displays the capabilities of the C2V used during OIF.[13]

In addition to the legacy MSE and DGM, as discussed in Chapter 3, the items listed in Table 3 were prominently used during OIF. Each system was used by U.S. and selected coalition forces preceding combat actions in Iraq. Further details on these systems may be found in Appendix D. While major units such as V Corps tested many of these systems in the months preceding action in OIF, some systems were added to the maneuver force as late as hours prior to forces crossing the LD into Iraq. Finally, a few commercial systems

TOE and MTOE sytems		COTS systems
DISN	GBS	INMARSAT
DSN	GIG	Iridium
DRSN	HF	Ku Band SATCOM
DTRACS	JWICS	Promina
FBCB2-BFT	MSRT	Thuraya
EPLRS	SC TACSAT	VOIP
FM	STEP	VTC

Table 3. Major TOE, MTOE, and Commercial off the Shelf systems of OIF

were procured by individual units to enhance their command and control abilities and network centric warfare capabilities.

Lack of a Single, Interoperable C2 System

A major flaw in joint and coalition systems for OIF was the lack of interoperability. Prior to actions in Iraq, Marine and coalition forces generally had no visibility of Army blue forces. Marine forces could see information passed from FBCB2/BFT into GCCS, but the Army could not see Marine units in return. The Marines would input information into C2PC from their blue PLI (position location information)—a line-of-sight system similar to EPLRS—into the GCCS, but the Army forces could not see the return information from GCCS. To compensate, Marine and coalition forces installed a limited number of FBCB2/BFT units on their vehicles. As Lieutenant Colonel Dave Pere, senior watch officer in the Ist MEF Combat Operations Center (COC) during OIF/ Operation Telic, said,

> *That all came to light right before the war…We realized that the Army was from Mars and we were from Venus, so we were quite literally putting Blue Force Tracker on our vehicles as they were coming off the ships…We wanted a whole lot more (then the 158 FBCB2/BFT sets provided). We still do. We want hundreds more. Because the thing about Blue Force Tracker is that you can also send e-mail on it. So we had one of the Blue Force Tracker monitors in the COC. I still had my C2PC, but I could also see Blue Force Tracker.*[14]

C2 on the Move

Leaders cannot afford to lose situational awareness of the fight or their ability to control its execution whenever they mount vehicles, helicopters, airplanes, or tracked/wheeled CPs. This war was characterized by unprecedented requirement for immediately available BCOTM capabilities throughout the tactical force. SC TACSAT's broadcast capability enabled swift changes to support operations against an unpredictable enemy. Blue Force Tracking provided situational awareness of friendly forces and their proximity to enemy locations. Both capabilities were used together to provide confidence in fire and maneuver, saving "countless lives," according to MG Blount, the commander of 3 ID.[15] For the COSCOM Commanding General, the Defense Transportation Regional Control System (DTRACS) and Movement Tracking System (MTS) became the major C2 communications network for the logistical fight.[16]

While SC TACSAT, FBCB2, and Iridium provided on-the-move capabilities to the force, the quantity was insufficient to equip every unit. V Corps did not come close to equipping the force with everything they needed. Consequently, they had to use MSE to augment their sparse and under-capable on-the-move systems.

Despite the introduction of OTM capabilities as described above, the vast majority of tactical leaders and CPs enjoyed few C2-OTM capabilities beyond FM. Consequently, they did not uniformly broadcast situation awareness, changes to orders, nor did they synchronize synergistic branches to missions across and through formations involved in fast, furious, and non-contiguous fighting.

Collaboration Tools

During OIF, units from all levels used Defense Collaborative Tools Suite (DCTS) as their collaborative tool. It was fielded throughout the corps and divisions and separate brigades, but it was only useful in a stable garrison like environment. It required a large dedicated bandwidth circuit to provide a quality product, and it was easily disrupted when the signal was passed through multiple relays, both terrestrial and space-based. LTG Wallace used DCTS as his C2 net for the first four days of the war before giving way to the much clearer, more reliable, effective, and OTM-capable SC TACSAT.

DCTS was used mainly to collaborate between small groups of users, but network limitations precluded its reliable use for multiple clients. LTG Wallace conducted daily DCTS sessions between his own C2V and/or corps TAC staff and his Contingency Planning Group (CPG) located at Corps Main in Kuwait. DCTS, and later InfoWorkSpace (IWS), was used in the theater with groups that could tolerate the interruptions. DCTS and IWS are unable to interoperate and the current designs are not a manageable solution for the tactical battlefield.

COTS and Interoperability

Over the past several years, individual units and commands have supplemented their units with a myriad of COTS systems. Some of this equipment was purchased as system and network enablers, while other items are purchased with year-end funds initiatives.

The Department of the Army G3/6/8 led these initiatives to procure the mobile command post module prototype, a limited number of HF and UHF SC TACSATs, and tracking systems for corps and MEF maneuver forces. Other programs requested by the combatant commands, and approved by DISA, included access to the NETCOM-installed TELEPORTS at Standard Tactical Entry Points (STEPs), authority to use commercial satellites, and the use of commercial terminals to extend DISN to corps and divisional command posts.

This tendency to use COTS has led to inconsistent modernization and an unsynchronized network infrastructure. As units have scheduled upgrades at different rates, this has caused too many different and non-compatible information systems to be fielded to the force. The Army has accrued a plethora of operating systems to suit particular battlefield requirements, but little interoperability or commonality. The lack of commonality between systems caused frustration for major subordinate commands during OIF. Commanders do not have the assets to effectively merge these systems into one COP. Generals Franks, McKiernan, and Wallace observed an information technology-enabled transformed battlespace, but they also observed leaders struggling with the limitations of their legacy networks and service-centric solutions.[17] As an example, the 3 ID DIVARTY monitored the following information systems at one time or another during OIF:

- Automated Deep Operations Coordination System (ADOCS)
- Command and control personal computer (C2PC)
- Maneuver Control System Light (MCS-L)
- Remote work station (RWS)
- All Source Analysis System Light (ASAS-L)
- Advanced Field Artillery Tactical Data System (AFATDS)

- Effects Management Tool (EMT)
- Joint Early Warning System (JWARN)
- Force XXI Brigade and Below C2 System (FBCB2)
- Terrabase/SPEED (Terrain Analysis and Profiling Systems)
- Microsoft Internet Explorer for access to 3 ID TACWEB
- Microsoft Outlook Mail to transmit FRAGOs

These systems presented a tremendous challenge to the DIVARTY staff in giving the commander information in a synchronized and homogenous manner. During combat operations, the DIVARTY was tracking the counterfire picture on ADOCS, unit locations where displayed via C2PC, and counterfire missions were initiated over AFATDS. DIVARTY was further challenged with the requirement to stand up a JWARN station to plot downwind hazards and to analyze possible jump locations for communications suitability on Terrabase. While some of these systems do, in fact, interoperate, most do not. The lack of a standard operating system, network protocols, iconology, and network interfaces for the various transmission media led to confusion and frustration with the systems.[18]

Lack of interoperability was seen in other areas as well. Warfighting and signal units arrived on the battlefield with different equipment sets, different degrees of modernization, and their own share of well-meaning, but non-interoperable materiel solutions. Regional Support Centers (RSCs) were not resourced to provide mobile command posts with direct support repair and replacement parts.

The GCCS-A is one example of a system that served to destabilize the joint COP. The Army's ASAS system provides a Common Intelligence Picture to populate GCCS-A. However, neither GCCS-A nor ASAS could interoperate with the MEF's intelligence system. As a result, the Corps, MEF, and coalition forces did not have a Joint Common Intelligence Picture or a COP.

The network implemented during OIF was a mesh of COTS and legacy systems that were kluged[19] together to provide commanders at every level with with C2 and situational awareness during OIF. The C2 capability and situational awareness that were provided went far beyond anything ever experienced in any other war ever fought. The infusion of satellite-based systems, tracking measures and e-mail exchange capabilities enabled effective synchronization of command and staff tasks at theater, operational, and tactical levels without regard to terrain or distance. Without this extended connectivity, the OPTEMPO of the offensive would have been greatly reduced, leaving the forces vulnerable to weapons of mass destruction and to higher casualty rates. COL Jeff Smith, the V Corps G6 stated,

> *If today's Signal Soldier can install MSE and DGM, lay wire and cable under fire, provide pre-configured routers to every Corps Command Post, acquire transponders in the sky; execute over the air exchange of COMSEC and Frequency HOPSETs, then he can execute the input functions required to operate a Command Post Module. Certainly no Commander or Staff Leader who fought Iraqi Freedom is going to turn back the C4 clock, or accept incremental upgrades to the status quo. None will wait on WIN-T. None expect perfection. The concept describes a network that's good enough. The proof of concept was the war itself.*[20]

5. C4 Programs of Record in the Wake of OIF

We can't have programs of record that are measured in decades; we have to have some agility in our capability cycle times.[1]

—Terry J. Pudas
Acting Director,
Office of Force Transformation

Programs of record are indeed measured in decades. They are appointed project and program managers by the DoD acquisition authority and have congressional oversight. They embody vision. They are goal oriented. Programs of record adhere to architectural frameworks, and they obey the laws and directives of the DoD acquisition process. As noted in Chapter 2, the initial requirement for MSE equipment was stated in 1979. MSE initial fielding began in 1989—a decade later. The system was well-suited for the Cold War defensive posture of Europe, but it was ungainly and sluggish for the swift movement to contact in the 1991 Persian Gulf War (Desert Storm), which ensued within two years of its fielding. The decade of the 1990's witnessed a paradigm shift in communications of every variety. Ubiquitous satellites, cell phones, e-mail, and the World Wide Web transformed not only how we communicated, but also transformed our expectations. This transformation would affect commanders at every level. The change in their communications expectations would change the nature of the future battlefield. Warfare would have to be network enabled and suitable architectures for net-centricity would need to be developed to meet these new, higher expectations. An era of network centricity was emerging.

Almost exactly one decade after Desert Storm, a Joint Requirements Operational Concept (JROC) established a new program of record to move tactical communications into the realm of net-centric communications. This program was entitled Warfighter Information Network Tactical or WIN-T (figure 20). It emerged as the Army embarked on the Chief of Staff's Transformation Roadmap under the DoD communications architecture umbrella known as the Global Information Grid (GIG). WIN-T would take full advantage of emerging network technologies and provide voice, video, and data for the warfighter. Although WIN-T was not the only program of record to pursue new network technologies, it is emblematic of the constraints that are placed on such programs by the acquisition process. Such constraints, although based on the laudable principles of congressional oversight and competitive bidding, can cripple efforts to shorten "capability cycle times." Following the rules and regulations as set forth in DoD Directive 5000.1 and other tenets prescribed for defense acquisition, project managers

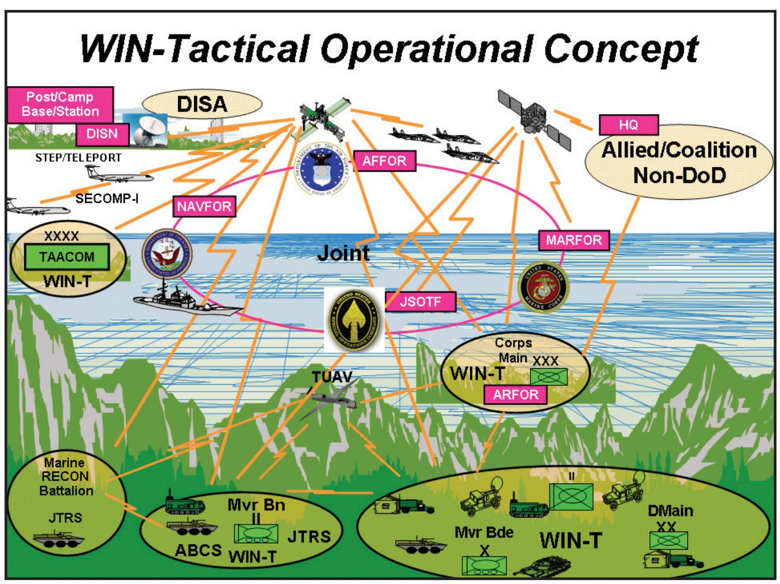


Figure 20. WIN-T Architecture, Theater to Battalion and External Interfaces.

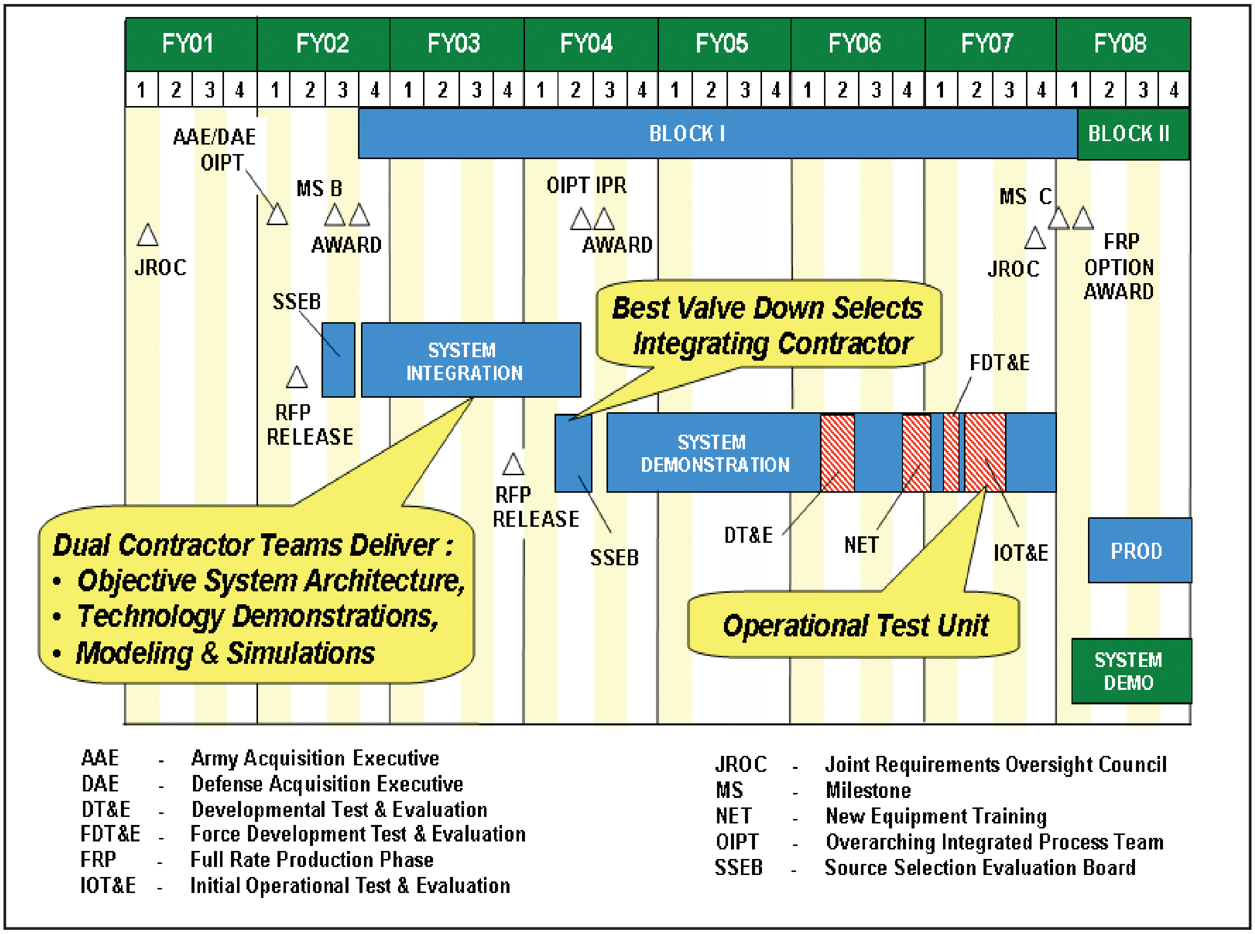


Figure 21. Warfighter Information Network–Tactical (WIN-T) Acquisition Schedule.

accept milestone schedules that span a decade or more. From its onset, the WIN-T program proposed a traditional acquisition strategy, despite the fact that briefings to the Army proclaimed that the MSE/TRI-TAC family of equipment was inadequate for both the present (circa 1998) and the future.[2] The traditional acquisition strategy shown in figure 21 was taken from a WIN-T briefing slide; it clearly depicts a decade-plus acquisition plan.

Project managers normally remain on their respective projects for only three to four years, virtually guaranteeing that the manager who starts a project will not be the same person who manages the fielding—maybe not even two successive milestone reviews. Furthermore, milestone reviews too often "slip to the right" in time, as the project goes through a series of budget cuts or reprogramming.[3] Sadly, such slippage and cuts are near-certain expectations. To be sure, WIN-T, in spite of its vision for rapid advanced technology insertion, is no exception to the normal capability cycle times that are built into the acquisition life cycle process for weapons systems hardware platforms. Hardware platforms do indeed incorporate new technologies, such as in metallurgy, hydraulics, and power systems. But such advances lag the information technology (IT) capability cycle times, as reflected in commercial off-the-shelf products. Growth in IT capability will cycle nearly five times in a decade.[4] Therefore, we can define IT capability cycle time today to be equal to two years (10 years divided by 5 cycles equals 2 years per cycle). Accelerated growth on the S-curve will

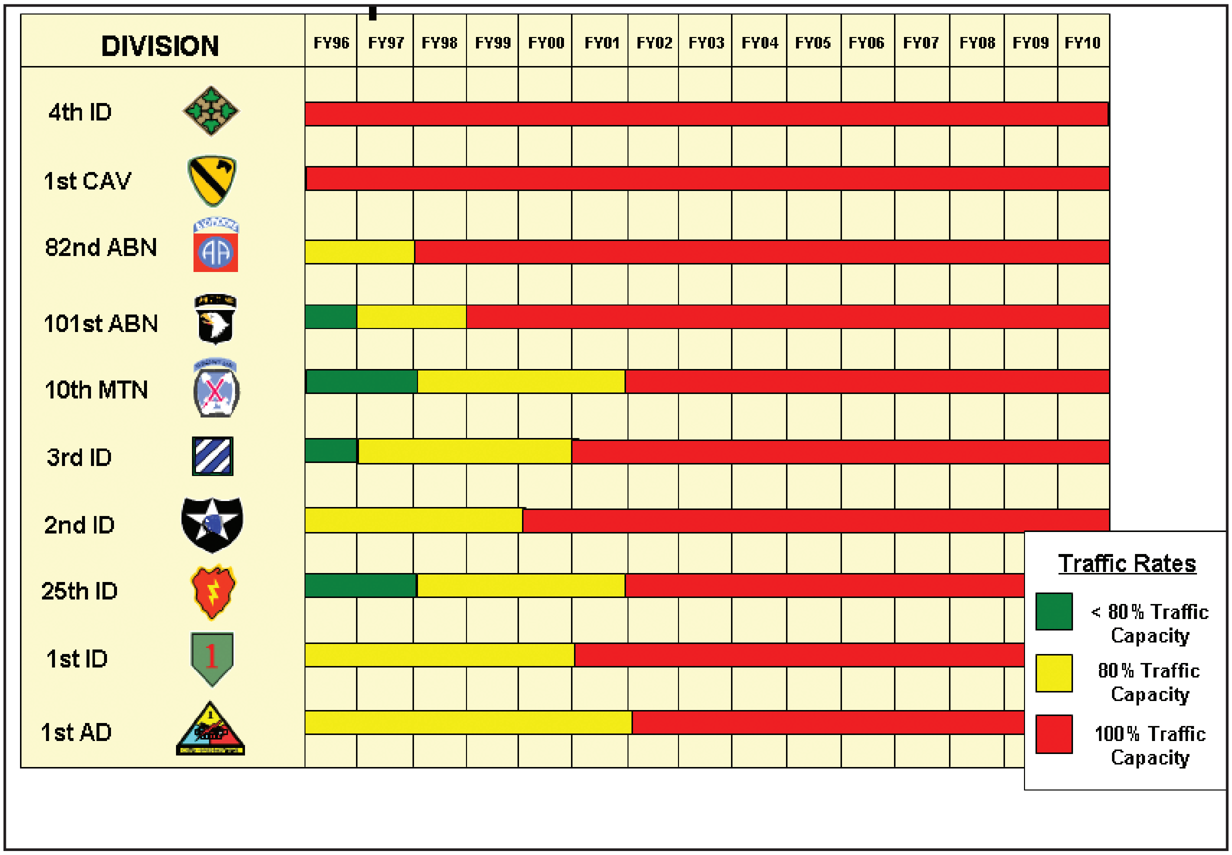


Figure 22: MSE Load Capacities by Army Division.

cause cycle times to be even shorter in the future. Spending ten years to field a system that will be "obsolete on arrival" is tantamount to programming failure in the next war.

A 1998 WIN-T briefing depicted the shortfall in MSE/TRI-TAC communications by tactical division: by FY02 no Army division would be capable of meeting wartime bandwidth requirements with MSE (see figure 22). This analysis sent an urgent message to the Army to support the WIN-T program. Block 1 for WIN-T fielding spanned five years (see the upper portion of figure 21) and provided technology insertions for MSE to increase bandwidth.

The need to increase bandwidth is spurred by exponential growth in video and data requirements (only marginal growth in voice needs), as shown in figure 23. Even though figure 23 depicts civilian source data, similar growth curves hold true for military requirements during net-centric operations. Figure 24, a radio data transfer rate chart from a WIN-T briefing, further supports this assertion. Once again, by the Army's own assessment, the communications readiness posture was unprepared for wartime operations.

A glaring question reveals the obvious predicament: how could the Army fight the next war lacking the capacity for anticipated communications requirements? From a communications architecture perspective—during a period characterized as a paradigm shift to network enabled warfare—there was no acquisition process capable of supporting the rapid infusion of available technology needed to meet the existent shortfall in communications capability in the fighting force. Indeed, it would take a decade to meet that shortfall; there was no agility in our capability cycle times. Tactical communications

project managers had no choice but to constrain themselves to the weapons platform acquisition model with its rigid milestone reviews, demonstrations, operational test and evaluation, low rate initial production, and fielding cycles.

Despite the ever-urgent responsibility to be combat ready for the next fight, the Army knew, as early as 1998, that the communications architecture could not support that fight. MSE was inadequate for all current and future voice, video, and data requirements, not to mention the requirement to provide communications on the move (COTM). It was already known in the immediate aftermath of Desert Storm in 1991 that MSE could not keep pace with the optempo of the battle, despite valiant attempts and field expedient methods on the part of signaleers.

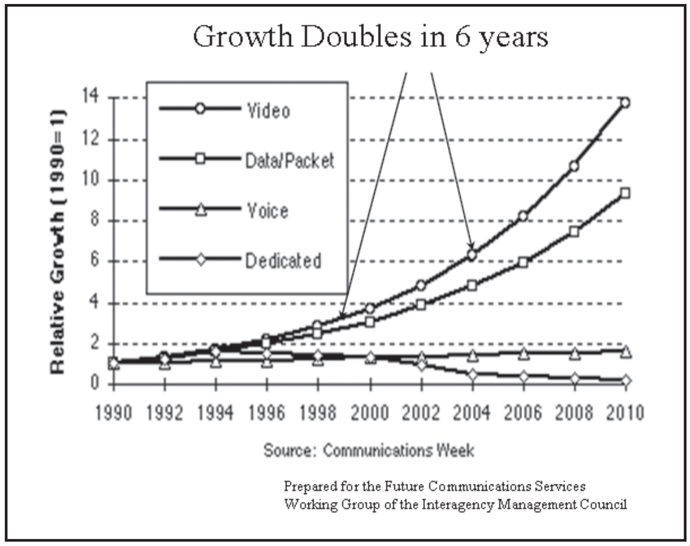


Figure 23. Relative Growth Rate of Voice, Video, and Data.

Bandwidth was not the problem. As shown in figure 23, there was negligible spread between voice, video, and data needs in 1991. Most people did not have e-mail, and the World Wide Web had yet to be invented. It was still about 3:00 a.m., before the dawn of the notion of network centric warfare. In fact, it was not until networks in general gave rise to the exponential increase in video and data demands that MSE was left woefully behind from a capability perspective. Figure 25shows a 1998 prediction of rising bandwidth requirements for a brigade tactical operations center (TOC). Frankly, before 1998 and the emergence of the WIN-T requirements, few had perceived the scope of the network's impact. Consequently, the military was unprepared for the immediate shortfall in bandwidth. The network was a disruptive technology—producing a new S-curve—that rendered the existing communications technologies obsolete.[5]

The NCW paradigm shift had resulted in a roughly three-year obsolescence horizon (see 1998 to 2001, figure 25). The acquisition cycle time remained ten years, or more. This guaranteed a serious capability shortfall. From a warfighting communications architecture perspective, what had to occur with the paradigm shift to NCW was a concomitant shift to an acquisition cycle time of three years or less to prevent the shortfall in bandwidth. This did not occur in 1998. Nor did it occur five years later on the road to Baghdad, the first real-world test of network centric operations.

We have portrayed the pre-OIF architecture in Chapter 3 to depict the TOE posture of the tactical U.S. Army communications architecture. Chapter 4 summarizes and portrays what had to be done in the eleventh hour to ready the force for communications in a highly mobile COTM environment. There were shortfalls during OIF to be sure. But there was also a grand, ad hoc infusion of capability under great duress within a year of the impending war. The less-than-one-year cycle time to equip part of the force with Blue Force Tracker is but one example of what can be done outside of the acquisition process to bring agility to capability cycle times. However, agility comes with a price. Understanding those costs, as well as the benefits, is vital to envisioning a future in which the U.S. militaries C4 architecture maintains a qualitative edge.

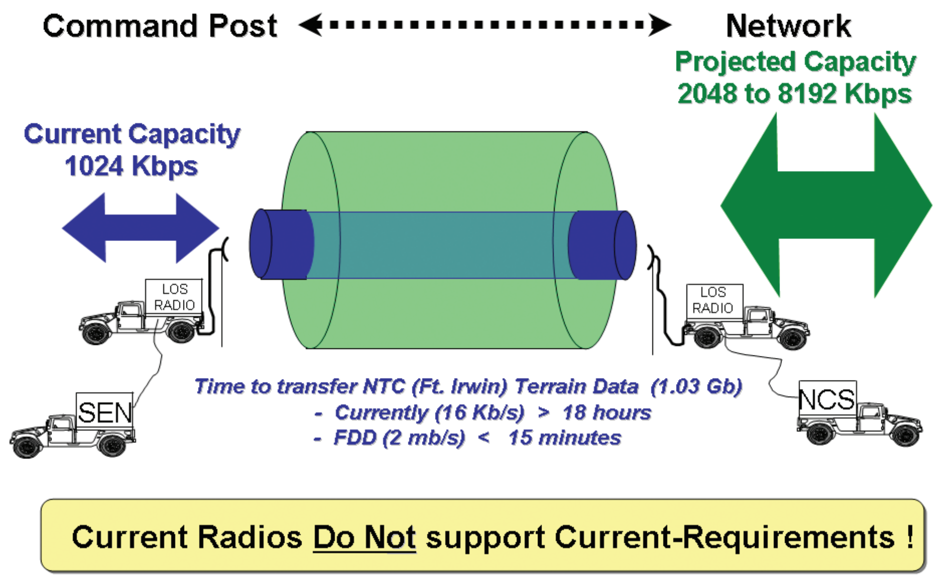


Figure 24. 1998 Assessment of Current (1998) vs. Projected (2008) Radio Data Transfer Rates.

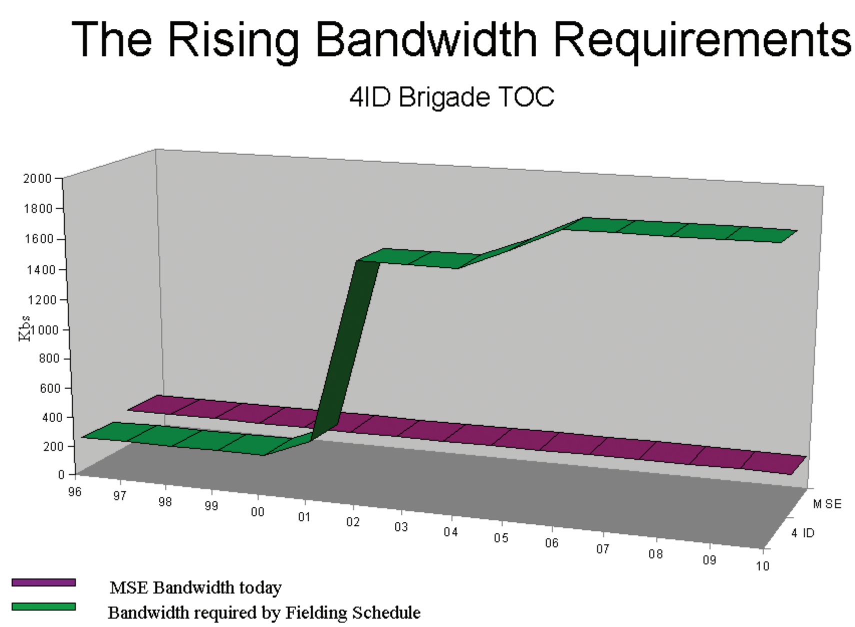


Figure 25. Rising Bandwidth Requirements Not Met by MSE from a 1998 Perspective.

Prudens Futuri

6. Un-Programmed C4 Architectures in the Wake of OIF

LIMITATION - Of the amount authorized to be appropriated by section 101(5) for other procurement for the Army and available for purposes of the procurement of the Joint Network Node, not more than 50 percent of such amount may be available for such purposes until the Secretary of the Army submits to the congressional defense committees a report on the strategy of the Army for the convergence of the Joint Network Node, the Warfighter Information Network-Tactical, and the Mounted Battle Command On-the-Move communications programs.[1]

—Senate Bill, S.2766

The time to fix bandwidth problems is now, before we deploy to the next fight.[2]

—GEN William S. Wallace

Everyone would like materiel acquisition in all three ways: good, fast, and cheap. However, we can only choose two, because the two we choose will inevitably eliminate the third. The quotations above serve to illustrate this point. On the one hand, a delay is imposed on communications programs by Congress because it wants to analyze the broader acquisition plan for next generation C4. On the other, the imperative for force readiness demands that there be no delay in fixing military operational and tactical problems. In the wake of OIF-1, the immediate C4 fix is an un-programmed solution known as the Joint Network Node (JNN).

The U.S. Army, riding the crest of congressional supplemental budget increases for follow-on OIF rotations, has been well on the way to fixing the C4 bandwidth problem good, fast, and cheap. Communications engineers at Ft. Monmouth, New Jersey and Ft. Gordon, Georgia, and a commercial contractor have created the JNN package. The JNN is not a program of record. As discussed previously, programs of record, like WIN-T, have purposefully rigid requirements and a milestone review process that lasts a decade or more. In his testimony before the House Armed Services Committee, General Wallace was clearly not asking to fix the C4 problem a decade from now. He wanted to be ready for the next fight. Chapter 2 documented attempts to project transformational technologies from 1920 to 2020. Predicting the future is difficult and inexact. Predicting the next war is even more imprecise. The “peace dividend” expected after the fall of the Berlin Wall signaled the end of the Cold War reminds us of how mistaken we can be about such predictions. Scarcely two years later, we fought Desert Storm. OIF followed twelve years after that. History is replete with the spontaneous eruption of armed conflict.

The U.S. Army fought OIF with an obsolete C4 architecture—MSE. This situation was a direct result of the sluggish response of the acquisition processes to the revolution in communications that occurred throughout the 1990’s. The communications TOE scarcely changed, even as the Army’s own analysis revealed that communication bandwidth across all of its divisions would

Joint Network Node Shelter

Ku Trailer

Figure 26. A Joint Nework Node Communications Shelter and Satellite Terminal Trailer.

be insufficient by FY 2002 (figure 20, Chapter 5). There was only a modest remedy in MSE equipment to adjust for the looming, exponential increase in bandwidth requirements. In his testimony, General Wallace deplored the difficulties of constructing an ad hoc C4 system in the seven months immediately preceding OIF.[3] There would have been no need to construct such an ad hoc package if the tactical military communications architecture could have kept pace with commercial and the fixed-station military enterprise information systems. What JNN did, and continues to do, is extend the military installation to the warfighter. And JNN provides sufficient bandwidth. In OIF, virtually every enterprise, including the DoD, had what combat soldiers did not—adequate bandwidth. There is no technical reason why JNN could not have been fielded anytime in this century before OIF-1. The next fight may not be predictable, but the C4 shortfall is avoidable. As General Wallace told Congress, the Army should never go to war without ample bandwidth again.

The JNN terminal extends voice, video, and data capability to the battlefield with a data rate and distance reach not replicable by MSE. In effect, it gives both the secure (SIPR) and non-secure (NIPR) internet to the soldier. Its "beyond line-of-sight" capability is made possible with the addition of a satellite communications terminal. All of this is packaged in a transportable communications S-250 shelter and a trailer transports the satellite communications terminal as shown in figure 26.[4]

An external view of the military S-250 and S-280 shelters reveals little difference between the JNN terminal and the last forty years of legacy equipment. However, there is a distinct difference on the inside. All of the components of legacy equipment were uniquely designed and manufactured radios, modems, and accessories. The AN/GRC-50 radio in the S-280 mounted AN/TRC-117 and the AN/GRC-103 radio in the AN/TRC-145 terminals had no civilian counterpart. Nor did the TD-660 multiplexer, which enabled multichannel communications over these radios. The data plates were telltale signs of the "built for military use only" origination of this equipment. But the commercial names on the components inside the S-250 shelter of the JNN terminal are like any other network facility in the commercial world or on any fixed-station military installation (see figure 27).

Figure 27. Example Commercial Equipment Components of JNN.

These Cisco™ routers and Promina™ switches are non-developmental items. Their combination in an S-250 shelter, configured to satisfy battlefield requirements, may be unique, but it does not require a decade-long acquisition process simply to impose configuration management. Immediately after OIF-1, the Army launched an ambitious fielding of JNN that solved a significant portion of the bandwidth problem. It used OIF supplemental funds to equip each division rotation into Iraq, beginning with the 3 ID in 2004. This fielding was unencumbered by the formal acquisition process of a program of record. In other words, JNN fielding was on track to be good, fast, and, at less than $100 million per division, cheap.[5]

The JNN was first fielded to the 3 ID for its second rotation to Iraq. During OIF-1, the 3 ID's 123rd Signal Battalion had been equipped with MSE. Upon returning to CONUS after OIF-1, the 3 ID had converted to a modular force, deactivated its signal battalion, and exchanged its MSE assemblages for the JNN suite.[6] This was a monumental effort. Faced with a twelve-month turnaround to Iraq, the division had to accept an expedited fielding plan. In less than a year, the division stood down its signal battalion and retrained its personnel with the new equipment, particularly the satellite systems operators. There were major perturbations in all of the DOTLM-PF domains, but the mission was accomplished. Significant, although often overlooked, was the need to change the division's signal MTOE. Changing an Army MTOE is an arduous and automation intensive process that programs and synchronizes all of the DOTLM-PF domains. Usually, a MTOE change takes about two years to accomplish. Conversion to JNN for the 3 ID had to be completed in months. The method used to move to the JNN-based MTOE was modeled on the method used when the Army formed Stryker Brigades.[7] The Army would be well-advised to capture these methods as a basis for "re-inventing" the MTOE process. The 3 ID's rapid conversion to a JNN-

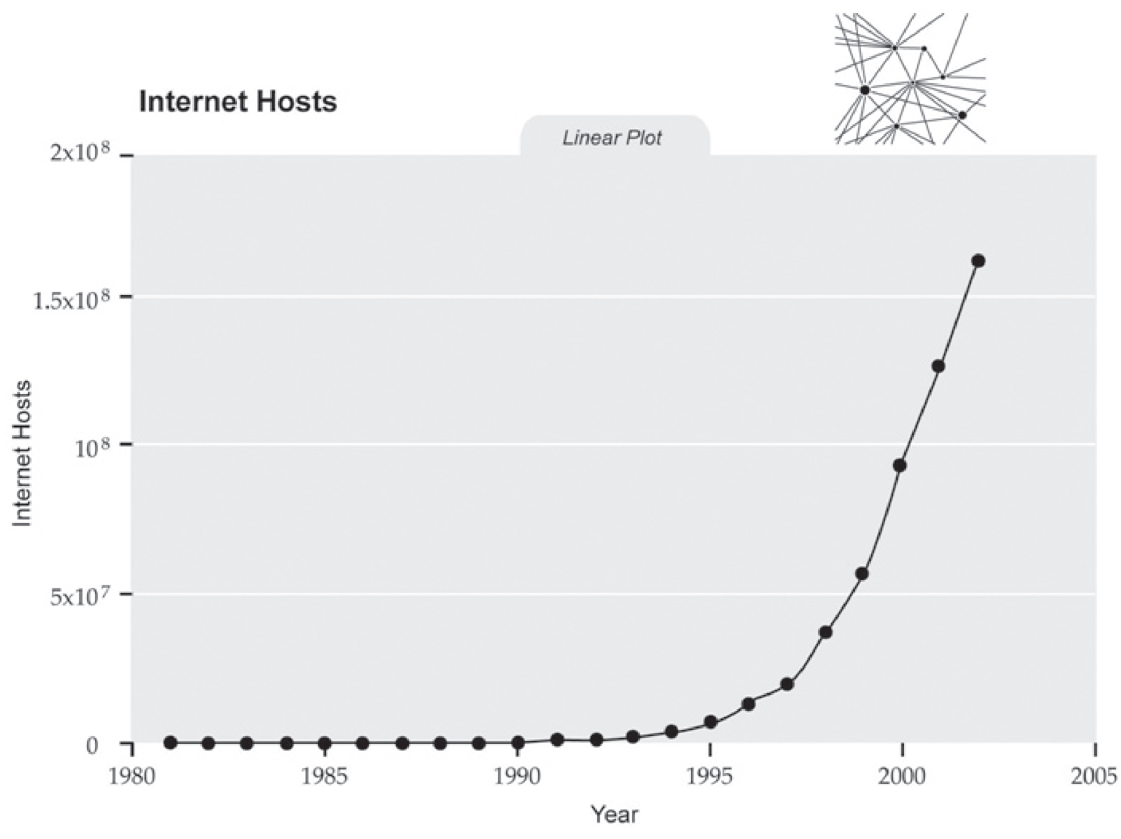
based MTOE foreshadows a future need to react swiftly to WIN-T and FCS products. In view of this, and the volume of rapid technology insertions envisioned for the future, the MTOE process must be changed to facilitate timely documentation of un-programmed fieldings.[8]

In early 2006, it appeared that the Army communications community would succeed with a 100% conversion of the ten active divisions, along with selected reserve force elements. This would have transitioned the current force from an obsolete MSE architecture to a net-centric architecture by the end of FY 2007. But this was not to be the case. Even though it was not a program of record, JNN would be subjected to an initial operational test and evaluation (IOT&E), just like a program of record. JNN was awarded initially as a sole-source procurement. However, programs of record almost always require full and open competition for a full rate of production. Now—after eight of the ten Army divisions have been fielded—JNN is required to comply with this competition rule. Competitive bids will have to be solicited for the remaining two active divisions. And even though JNN was yielding real-time results in a real-time conflict, Senate Bill S.2766 decreed that the remaining fielding had to be delayed to allow for a "convergence strategy" with WIN-T. But in July 2006, the WIN-T schedule slipped five years from initial operational capability (IOC) fielding in 2008 to an IOC in 2013. If JNN fielding remains tethered to the WIN-T program, the fielding of JNN will be neither as good nor as fast, as it almost was. And it will certainly be more expensive.

The method used to field current C4 technology, as employed in the fielding of JNN to date, is worth a closer look, particularly with regard to net-centricity architectures and non-programs of record. First, it should be recognized that JNN is "commercial equipment packaged in tactical shelters [that may be likened to] an internet department on wheels."[9] This differs from legacy equipment in the tactical communications architecture, virtually all of which was uniquely built for the military. The commercial components of JNN are used for both strategic and tactical communications. Historically, legacy systems were limited to either strategic communications or tactical communications. Equipment in the tactical communications architecture was rarely found at echelons above corps or theater operations. Like weapons systems that had no commercial application, legacy tactical communications equipment was deemed to be a similar type of procurement item. Consequently, the same Federal Acquisition Regulations (FAR) and DoD acquisition regulations were applied. Until the mid-1990's, there was no widespread use of the Internet, and communications were largely "point-to-point" or one-to-one. On the battlefield, this meant higher-to-lower, left-to-right, and supporting-to-supported, in accordance with Army doctrine. However, the Internet grew by a factor of nearly 3000 between the first fielding of MSE in 1988 and the preparation for OIF in 2002 (see figure 28). This explosion of network capability would provide the impetus for the notion of net-centricity, a notion that would radically change the approach to communications. Net-centricity invites everyone to be peers, with shared information in a collaborative environment. Everyone connected to the network was "IP-addressable" and as easily reached as anyone else on the planet at the speed of light. The network has leveled the communications playing field. Everyone is a player; there is no second string on the bench. A military communications architecture that would facilitate network connectivity would essentially have no demarcation line between strategic, operational, and tactical players. The equipment to facilitate this architecture at each level would be indistinguishable as well. JNN is a node on the network like any other node. It enables its users to be IP-addressable and to pass large quantities of voice, video, and data in a one-to-many fashion.

From a hardware component perspective, opening the back of the S-250 shelter that houses a JNN terminal is not unlike opening the door to any commercial or military installation information management department.[10] Yet installation network managers do not fall under acquisition laws and regulations. Why should JNN? Both JNN and the installation networks merely extend internet services to the same personnel, the only difference is that JNN is mobile and displaces to new locations. The commercial equipment items configured in the JNN terminal are treated simply as commodities anyplace else inside or outside of the government. They have upgrade and replacement cycles reflective of modern commercial practices to keep enterprises technologically current.[11]

Another example of success in non-programs of record is the Command Post of the Future (CPOF). The CPOF was a nascent project at DARPA when its potential was recognized by Army commanders. It first deployed with the 1st Cavalry Division in January 2005. CPOF allows topographic and operational overlays to form a common operating picture with timeline and data spreadsheet views of the battlefield situation. It is also a collaboration briefing tool. It was in use, as of this writing, by the 4th Infantry Division in Iraq.[12] The CPOF is being tested in Iraq and modified to conform to requirements and technical refinements. Although there were initially



Courtesy of Ray Kurzweil, *"The Singularity is near."*

Figure 28. Exponential Growth of the Internet Begins after 1995.

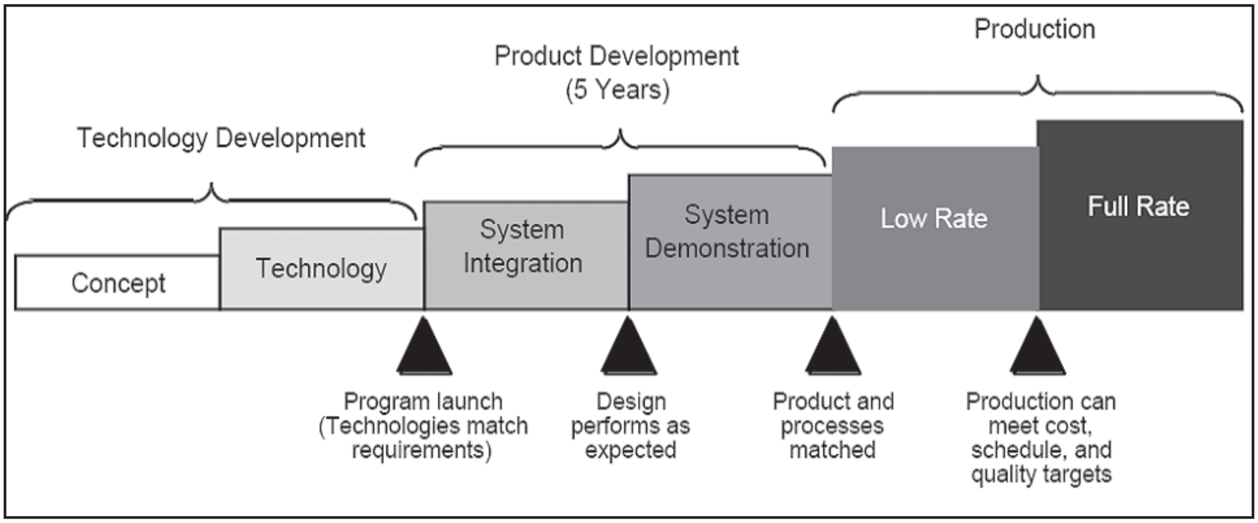


Figure 29. Best Practice Schedule for Product Development.

latency difficulties and other technical anomalies when transporting CPOF data over satellite links, these difficulties are gradually being overcome. A chief benefit of CPOF is its capability to provide a virtual meeting place and a joint mapping toolkit (JMTK). This enables unit commanders to meet electronically without having to physically travel to meetings, a hazardous endeavor in the Iraq theater of operations.

CPOF went from DARPA to Iraq in twelve months time. Not even the best practice scenario, which spans a minimum of eight years, would have met that timeline. Figure 29 shows a best practice schedule designed to expedite the early insertion of technology. The schedule is based on the use of technology readiness assessments (TRAs). The goal of TRAs is to reduce risk and life-cycle costs by selecting the optimal time to insert a new technology into the field.[13] These best practices are intended for programs of record. They are still too rigid to accommodate a rapid technology insertion in response to the ever-accelerating expectations of commanders in the field.

Policy makers and acquisition officials must realize that the network is a single entity and that its nodes—regardless of where or how they are employed—are configured with commercial equipment, and commercial internet equipment configured in a transportable military shelter is nothing more than “installation IT on the move.” It continues to provide fighting soldiers with at least the same robust information services they were equipped with when in garrison. With the exception of military satellites, the era of military-unique components for transporting data has passed.[14] The new era demands new processes for acquiring, maintaining, and replacing the network-enabling commercial electronics required to keep C4 architectures technologically current.

There is, however, at least one reservation with respect to JNN and CPOF that must be considered. There are three views in the C4 architecture framework—operational, systems, and technical. The complexity of “getting it right” for any subordinate architecture or system requires as much effort and rigor as is usually found in a program of record. While such effort and rigor translates into longer timelines for such programs, it can also be considered a positive aspect because adherence to framework standards is embedded in the longer process. Perhaps this is what the Senate bill seeks. Conformance to a governing or overarching architecture should not be given short shrift.

The short “flash to bang” time in which JNN and CPOF became mission capable is a testimony to the hard work and inventiveness of the engineers tasked with this mission. But it is admitted that JNN is not yet in full compliance with all of the architectural views, although there is a migration path to do so.

Products such as JNN and CPOF are informal because they bypass the formal acquisition process. These informal systems may initially be, in terms of the C4 architecture, immature, but over time, they can grow into compliance with architectural standards. There is a balance that must be maintained between urgency and correctness. During wartime, the balance must necessarily tilt in favor of urgency. In war’s aftermath, a more deliberate fielding schedule that ensures conformance to the architectural views should be favored. Unfortunately, JNN will no longer be fielded on a wartime schedule—although the war is far from over.

As of this writing, it is likely that the remainder of the JNN program will be converted to a program of record and, in some way, be linked to the WIN-T program.[15] WIN-T technologies will spin off into JNN, while WIN-T products themselves will be deferred to a year 2013 IOC. The exact relationship between the two programs will be determined at a later date—probably in response to Senate Bill S.2766. JNN was almost the first “poster child” of a good, fast, and cheap acquisition process. Sadly, it fell just two divisions short.

7. Envisioning C4 Architectures for the Foreseeable Future

The very essence of leadership is that you have to have a vision. You can't blow an uncertain trumpet.[1]

—Rev. Theodore M. Hesburgh
President Emeritus, University of Notre Dame

By the end of the 1990's, the intricacy and complexity of communications technology was having a serious impact at all levels of business and government. The relative simplicity of stringing wire from point to point, preparing message formats on a typewriter, or mechanically passing a paper tape from a German unit to its U.S. ally were in the past. Message volume was now counted in billions of bits, and words like "megabytes" were as common to school children with hip-slung music devices as they were to the scientists and engineers who created the capability.

As connectivity increased, we entered the era of systems of systems. Complexity began a cascade toward chaos. As traditional architecture had become more complex in the evolution from mud huts to skyscrapers, so had communications architecture become increasingly complex at the dawn of the information age. To make matters worse, the communications landscape quickly became littered with "skyscrapers" of every variety with designs equally diverse and dissimilar. They did not fit together, but they were going to have to work together. A vision was required of a common, overarching architecture to create a modern landscape of inter-connected structures that would function together harmoniously to the benefit of all concerned.

When innumerable communications architectures arrived on the scene almost simultaneously, as they did at the end of the twentieth century, there was an overwhelming need to identify an overarching architecture.

The primary issue is interoperability. At some point, dissimilar entities will have a requirement to intercommunicate. At that point, there needs to be a common interface. A teletypewriter that only produces three-quarter-inch tapes cannot read a one-half-inch tape. Modern communications systems using different architectures clash in the same manner.

Many enterprises have long recognized and tried to resolve problems of communications interoperability. In the 1970s, the NATO Integrated Communications Systems Management Agency (NICSMA) was formed to resolve C3 differences between North Atlantic treaty countries. Yet there were also significant problems to resolve in joint, U.S.-only operations, as was manifested in 1983 in Grenada during Operation Urgent Fury. In 1996, the Clinger-Cohen Act assigned Chief Information Officers (CIOs) of the federal government the responsibility to establish information technology architectures. In 1998, these CIOs set out to develop the Federal Enterprise Architecture Framework (FEAF) to more easily share information and solve interoperability problems within the federal government.[2] This was a lofty but essential goal and, despite what public media pundits would have the citizenry believe, ahead of its time. In fact, even before work began on the FEAF,

- Army Battale Command System (ABCS) Architecture
- Army Intelligence Operational and Systems Architecture
- Army Knowledge Enterprise Architecture (AKEA)
- Army Space Operational Architecture
- Battle Command System (BCS) Architecture
- Battle Management Command and Control (BMC2) Architecture
- DoD C4ISR Architecture
- Combined Enterprise Regional Information Exchange System (CENTRIXS)
- Deployable Joint Command and Control (DJC2)
- Family of Interoperable Operational Picture Architecture
- Federal Enterprise Architecture (FEA)
- Future Combat System (FCS) Architecture
- Global Information Grid (GIG) Architecture
- GIG Enterprise Services
- Global Reach Interactive Fully Functional Information Network
- Intelligence Community Communications Architecture
- Joint Technical Architecture (JTA)
- Legacy force and system architectures
- Joint Operational Architecture (JOA)
- Joint Command and Control (JC2) Architecture
- Joint Tactical Radio System (JTRS)
- Mission Information Management Communications Architecture
- Multilateral Interoperability Programme (MIP) Architecture
- NATO C3 Technical Architecture
- Net-Centric Enterprise Services (NCES)
- Objective Force Architecture
- Software Blocking (SWB) Architecture
- Single Integrated Ground Picture Architecture
- Situational Awareness Data Interoperability (SADI) Architecture
- Space Communications Architecture
- Standing Joint Force Headquarters (SJFHQ) Architecture
- Transformational Communications Architecture
- Unit of Employment (UE) Architecture
- Unit of Action (UA) Maneuver Architecture
- Warfighter Information Network-Tactical (WIN-T)

Table 4. Examples of DoD Architectures.

the DoD was at work putting together the C4ISR Architecture Framework, the first among federal agencies to tackle this problem.[3] The rationale was compelling. As Table 4 shows, there were literally scores of architectures to contend with in DoD alone.

Combining all of the communications aspects of warfare into an integrated and interoperable system was essential to swiftly defeat an enemy with minimal loss of allied forces. At the dawn of Network Centric Warfare, the science of modern command and control would be based on a firm communications foundation. The Urgent Fury and Desert Storm lessons learned had underscored the critical need to have an overarching architectural framework for C4. Future warfare on a large scale would be data- and weapons-platform-intensive. Readiness for the next armed conflict would require a C4 architecture that covered all of the armed services, intelligence agencies, and allied partners.

As the C4ISR Framework was being drafted, the Secretary of Defense issued the May 1997 Quadrennial Defense Review (QDR). With reference to the non-defense world of interconnectedness and internetted communications, the QDR named five principal components of the C4ISR architecture for 2010 and beyond:[4]

- A robust multi-sensor information grid providing dominant awareness of the battlespace to our commanders and forces;
- Advanced battle-management capabilities that allow employment of our globally deployed forces faster and more flexibly than those of potential adversaries;
- An information operations capability able to penetrate, manipulate, or deny an adversary's battlespace awareness or unimpeded use of his own forces;

- A joint communications grid with adequate capacity, resilience, and network-management capabilities to support the above capabilities as well as the range of communications requirements among commanders and forces;
- An information defense system to protect our globally distributed communications and processing network from interference or exploitation by an adversary.

It is DoD policy that the GIG shall:

4.1 Support all DoD missions with information technology

4.2 Plan, resource, acquire, implement in accordance with DoD 5000 series directives

4.3 Be compliant with the operational, system, and technical views

4.9 Maintain an enterprise-wide asset inventory

Responsibilities:

5.1.3 Provide a DoD-wide mission area architecture framework to build integrated operational, technical, and system architecture views.

5.1.5 Establish GIG compliance and enforcement mechanisms to achieve IT and National Security Systems (NSS) interoperability

5.2 Ensure architectures developed to meet combat support and business needs … reflect and utilize current and planned common GIG assets

5.3 Fully consider documented GIG requirements and architecture in the development of C4I Support Plans … and for advanced concept technology demonstrations

5.5 Ensure that GIG-related operational test and evaluation addresses all critical operational issues, including interoperability and information assurance

5.6.2 Develop joint doctrine for the GIG.

Within two years, the “grid” (see bullets one and two above) would become known as the GIG. The GIG concept includes a broad range of hardware and software providing extensive services and capabilities for peace and war.[5] It is envisioned to become the enabler for all communications and weapons platforms among the services and relevant non-DoD agencies.

On 19 September 2002, DoD Directive 8100.1 announced the Global Information Grid (GIG) Overarching Policy. Among other key policies, 8100.1 made compliance with the GIG architecture mandatory for all voice, data, and video products for combat operations.[6] For every agency that originates and shares battlefield common operating picture components, the GIG has become the overarching or capstone architecture for combat operations.

To make such a grid workable, a Net-Centric Data Strategy was adopted and promulgated by the DoD Chief Information Officer on May 9, 2003.[7] This strategy and its later implementation guidance was a giant step in furthering standards among data elements across the wide array of systems and services within and connected to the DoD. Unquestionably, the GIG was destined to become the “traffic cop” for DoD data. Not only would it be the ubiquitous construct for transporting DoD data anywhere and anytime, but it would also ensure that data from any system on the GIG can be used by any other system plugged into the GIG. In commercial parlance, this is referred to as a “plug and play” system. Approximately six years after the emergence of the notion of network centric warfare in 1995, an overarching architecture to enable NCW was already emerging, as were the policies that would put teeth behind the essential architectural requirements.

The QDR of 2001 was the first to fully develop the concept of networking and communications. It emphasized the increased reliance that warfighters would have on C4ISR architectures, science, and technology. Fully twenty pages (one-third of the QDR) are devoted to Section V, entitled “Creating the U.S. Military of the 21st Century.” Laced throughout that section is a steady stream of phrases promoting science and networks:

> *Leveraging information technology…to develop an interoperable, joint C4ISR architecture… increasing dependence…on advanced information networks…new information and communications technologies hold promise for networking highly distributed joint and*

combined forces…. Information technology holds vast potential for maximizing the effectiveness of American men and women in uniform…developing transformational capabilities through increased and wide-ranging science and technology…need compatible systems and interoperable standards…[Standing Joint Task Force headquarters] will have a standardized joint C4ISR architecture…networked to maximize their combined effects… exploitation of…nanotechnology…advanced parallel processing and quantum computing… biometrics… research and development for stealth platforms and unmanned vehicles…[8]

Underlying all of this emphasis on networking, communications, and science was the late 1990's concept of transforming the DoD. Transformation envisioned forces organized to be lighter, agile, and more independent—yet more jointly interdependent. Unmanned vehicles in all domains would be inserted into the force along with orders-of-magnitude greater bandwidth for voice, video, and data. In response, each service developed its own sub-network portion of the GIG. The Army's portion is called LandWarNet.

The Army's next force is the Future Force. It will be built upon platforms of the Future Combat Systems (FCS). The diagram at figure 30 depicts a fifteen-year composite of the major Army C4 initiatives enroute to that future force. The diagram covers the period from 1998 to 2013 and depicts the transition from legacy systems (MSE) up to the maturity of WIN-T—the last system before FCS. It also shows the effect of technologies spun off of FCS that can be appliquéd to WIN-T early. Though not to scale, capability is shown increasing over time as the force capitalizes on advances in technology.

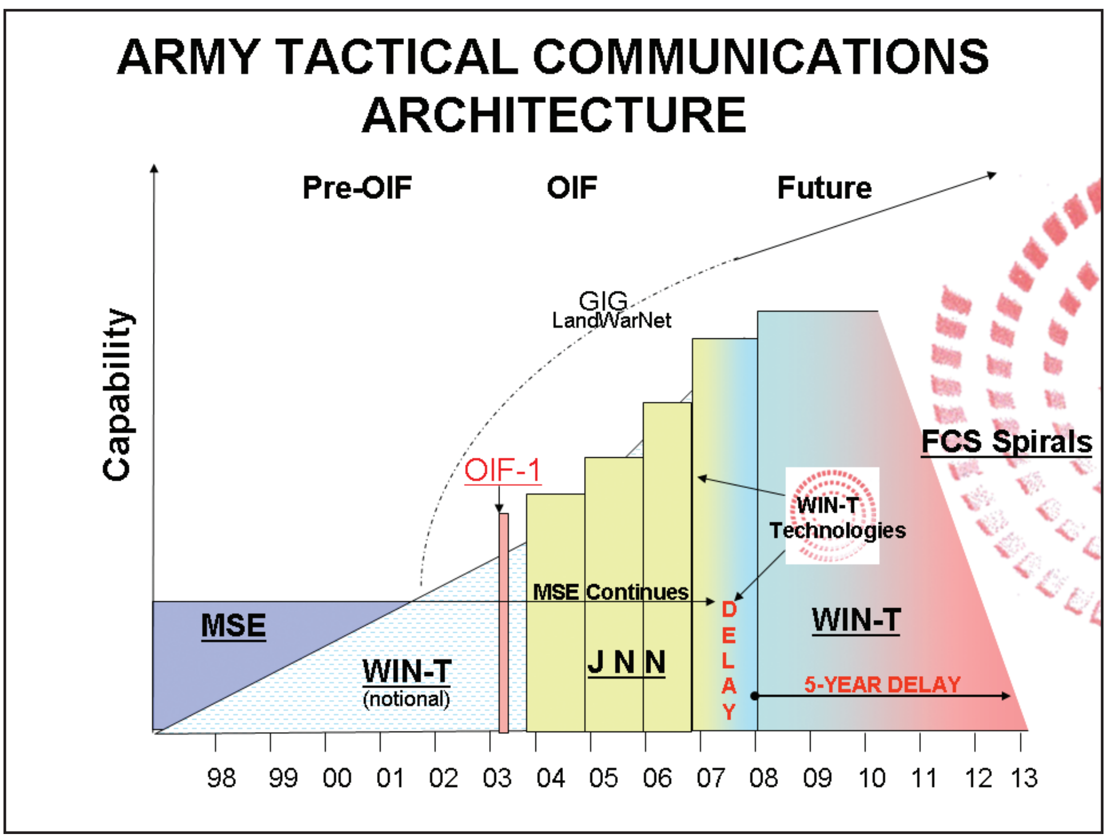


Figure 30. Army Tactical C4 Architectures; Capability versus Time.

Figure 30 reflects that the legacy MSE system will remain in the force for some time, as shown by the arrow extending to the right. WIN-T has been evolving since the late 1990's. It is expected to yield its first products by 2008.[9] Spin-offs of WIN-T technology that have recently matured will be inserted into the JNN suite. WIN-T products will merge with FCS "spirals" that spin off products incrementally as technologies mature for insertion into the Army. LandWarNet for the Army will be provided by the GIG. The GIG will be the overarching architecture for subordinate layers of architectures not only for the Army, but for Joint and coalition forces as well. Every layer will have to conform to GIG standards. The March-April 2003 time slice labeled OIF-1 is key. There are at least two communications architectural impacts resulting from OIF-1. The first is the significant change in slope of the developing WIN-T capability line. Second, the partial fielding of JNN to satisfy the immediate needs of successive rotations of units into Iraq (discussed in Chapter 6) brought unprogrammed communications capability to the force. Although the immediate increase in capability for the warfighter was advantageous for our soldiers and the mission, it was counterproductive with respect to long-term architecture conformance. To rectify the architecturally disruptive insertion of JNN and other OIF communication augmentations, the Army has embarked on an IT Short Term Migration Plan.

JNN is not alone. There is a mass migration of system architectures to a common standard. Most of the world we live in has been built with a "bottom-up" approach to development. A bottom-up approach typically does not begin with a global view of or a common need for an integrated system. The move toward commonality emerges later as needs arise. Currencies, railroad gauges, and units of measure remained as local standards until they expanded and touched other systems. On the

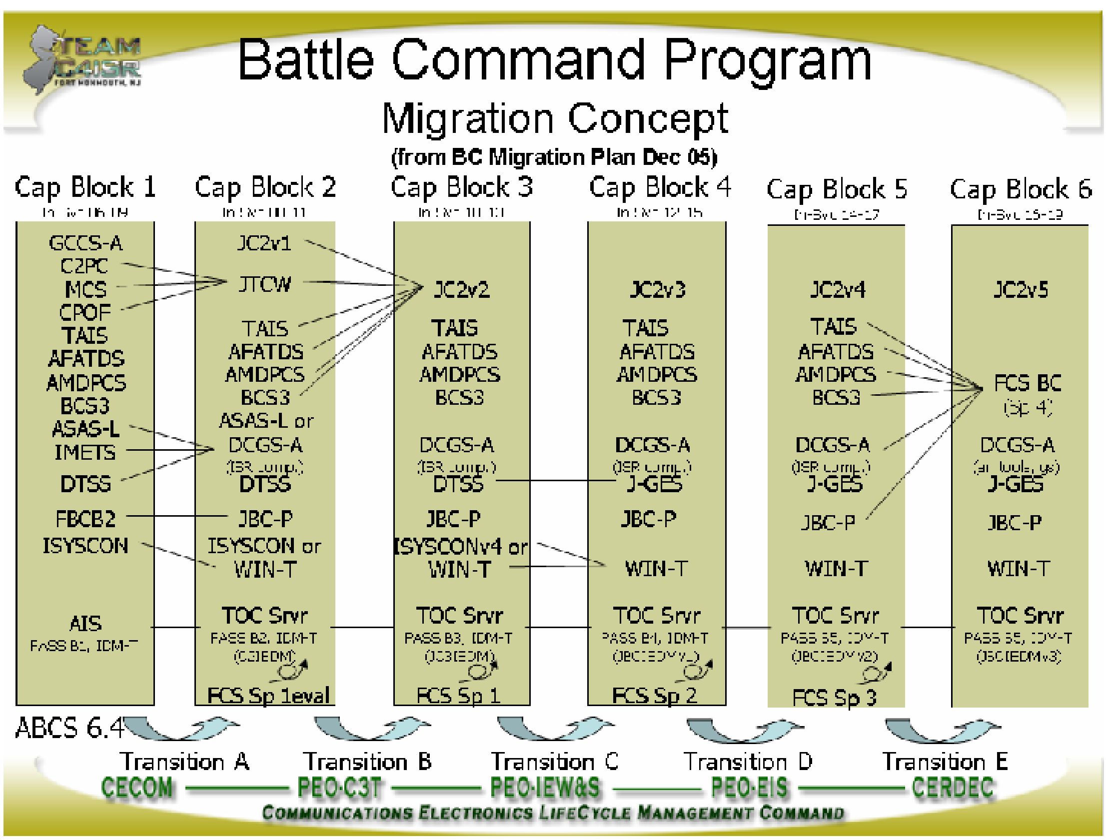


Figure 31. Battle Command Program Migration Concept[10]

other hand, “top-down” development requires a clear vision of the future and a desire for universal standards. Few enterprises have the authority or the will to demand top-down development, and few have the resources to lead and finance a top-down developed system. Therefore, it is normal for systems to emerge harmoniously but to remain independent from one another. To achieve common goals, a migration plan that leads to integration and standardization is needed.

The challenge for producing a common C4 architecture lies in the requirement to migrate many bottom-up developed systems towards fewer, more highly interoperable systems. The fuel for producing a migration plan is a mixture of vision and its co-requisite, leadership. The Army Battle Command Program has such a migration plan (see figure 31).

This migration plan spans thirteen years in five increments, referred to as Transitions A thru E. It incorporates four FCS spirals, and collapses the fourteen major programs depicted in Cap Block 1 down to seven. Throughout this migration, adherence to GIG standardization is required.

Maintaining a qualitative edge in combat effectiveness requires vision, and to paraphrase this chapter’s opening quote, vision is the essence of leadership. Thus it should come as no surprise that the U.S. military, with its leadership ethos, has envisioned a common C4 architecture.[11] However, merely envisioning the future will not sustain the qualitative edge we seek. Our processes must support our vision. We will not maintain that qualitative edge if technology continues to evolve five times faster than our acquisition process can make and implement a decision.

8. Meeting Accelerated Expectations: Sustaining the Vision

Though we have heard of stupid haste in war, cleverness has never been seen associated with long delays.
—Sun Tzu, the Art of War

There is a need for a Future Acquisition System in order to develop a Future Combat System.

Currently, we are faced with two options for bringing technology to the force. Programs of record are rigorous and they ensure standardization, complete integration of all the DOTLM-PF domains, and ample oversight. However, they are slow and cumbersome. Non-programs of record are far more agile and responsive, but they tend to be less rigorous, ignore standardization, take shortcuts around the DOTLM-PF domains, and escape oversight.

Prior to OIF-1, programs of record for Battlefield C4 systems did not keep pace with the available technology. The legacy MSE architecture had been lagging doctrine since Desert Storm. Lessons learned from that conflict had spawned notional C4 systems for the twenty-first century battlespace at the same time that such systems were emerging in the private sector. Many C4 battlefield technologies could have been produced and fielded sooner.

The biggest problem was a shortage of bandwidth, and WIN-T was supposed to be the answer. However, WIN-T was born in peacetime, with the long-term view of conformance, test, and the deliberate planning for each of the DOTLM-PF domains that is reflective of good project management. When the planning for OIF began, WIN-T still faced years of acquisition process. Faced with a serious shortfall and no program in sight to fix it, a JNN-like upgrade to the force was in order. The technology had been available when the paradigm shift to net-centricity was recognized—and Army Transformation was first advocated—and when MSE was proven to be inadequate for the next fight. In the three years since the war, JNN has been 80% fielded throughout the Army. The bandwidth fix, petitioned for by General Wallace, is almost complete. Meanwhile, WIN-T fielding is now slipped to 2013. We do not know when the "next war" will begin, but it could certainly begin before 2013. It may make sense to alter the political and acquisition view of non-programs of record, such as JNN.

Since OIF, commanders and loosened congressional purse strings have supported the immediate development of JNN to enhance the follow-on units with better, state-of-the-science C4 network technologies. Each rotation of forces after OIF-1 has enjoyed a better suite of JNN capability. To be sure, this rapid acquisition strategy is keeping pace with the best that technology can provide. Unfortunately, limitations under non-competitive acquisition procedures will require JNN to revert to competition to field the last two divisions. This may result in a superior product, but JNN will become a program of record and experience the burden of such programs. It will appear to be a competitor of WIN-T and suffer budget cuts and timeline elongation. This internal competition could duplicate effort, which will result in waste and inefficiency. In any budget, war or peace, duplication of effort is wasteful and inefficient.

"Vision without funding is just a hallucination."[1] Architectures at the dawn of Network Centric Warfare need money—a lot of money—to become real, to become enabling, and to become internalized. For the Army, two C4 architectures will embody the network over the next twenty-five years. They are the $10 billion WIN-T program and the $125 billion Future Combat System, the second-largest Pentagon procurement program in history.[2] These programs may espouse a transformational vision, but they are deeply funded, and therefore, not hallucinations.

Both programs have an architecture in conformance with the C4ISR Framework, complete with the requisite operational, systems, and technical views. They comply with applicable regulations and acquisition laws. They have Congressional oversight, formal milestone reviews, and test schedules. They are built on firm DOTLM-PF foundations and based on joint interoperability requirements. But bureaucratic burdens portend that these systems will be near obsolescence on arrival. Their timelines, as mandated by the acquisition process, will be overlong, and production and fielding are sure to be further delayed by "salami slices" in their funding stream: the predictable drawbacks of programs of record.

The nine-month "flash-to-bang time" to field Blue Force Tracker prior to March 2003 is a prime example of a non-programmed fielding and demonstrates the degree to which—with a lesser regard for DOTLM-PF, direct oversight, and competition—we can reduce the time lag produced by long-lead-time acquisition cycles. Systems like JNN, CPOF, and myriad COTS devices are "anti-architectural." They bypass the requirements of the three architectural views demanded by the Framework. Hence, the drawback of un-programmed fielding is the risk inherent in C4 programs that do not adhere to the C4ISR Framework.

On the other hand, adherence assures long-range interoperability standards and validates the architectural views. From this perspective, we find that the GIG, a program of record with all of the attendant encumbrances, best exemplifies the engineering rigor required for a realizable global network.

If it can truly provide for a C4 "plug and play" capability, then perhaps the GIG architecture is the long-sought capstone architecture for NCW.

Moore's Law guarantees that new technology for the warfighter will always be sitting on the COTS shelf before it can be assimilated into a long-lead-time program of record. In wartime, commanders have every right and reason to demand immediate off-the-shelf solutions, regardless of long-term C4 architectural consequences. Ongoing operations at corps and below continually engender new required operational capabilities for C4. Commanders in the field impart an urgency that demands near-real-time product delivery to meet the warfighter's needs. If the acquisition process does not meet their needs, they will seek alternatives. They will buy un-programmed COTS equipment, and they will pull nascent systems like CPOF from incubators like DARPA. These ad hoc systems will be "fielded" by contract developers and tested on the battlefield. They will probably not be in full compliance with the prescribed Framework for C4ISR architectures. As a result, after the war, the C4 architecture tower will need considerable shoring up, lest it topple. Clearly the solution lies in enabling the faster, more agile testing, fielding, and upgrading of future technologies.

Unlike the traditional acquisition model, un-programmed fielding is "customer-based," driven by commanders' accelerating expectations. The traditional acquisition process begins with a threat assessment. A new materiel acquisition is not the first course of action, but comes only after changes to doctrine or an existing system are not feasible. If the only feasible course of action to

meet the threat is a new program, then the acquisition life-cycle process begins with a required operational capability (ROC) and the appointment of a program/project/product manager. This begins the decade-long procurement process described earlier.

During that ten-year process, our potential adversaries sit at the same point on the S-curve as we do, with the same access to COTS products. Many adversaries, especially non-state actors, do not have formal acquisition processes. They buy state-of-the-science technology when they want it: no milestone reviews, no competitive bidding, no operational test and evaluation. Their "capability cycle time" is likened to a Saturday at a flea market. If better technology arrives two years later, they go back to the flea market. The greatest danger will result from a disruptive technology that is identified, acquired, and used against us before we have even written the ROC.

The future acquisition process must be capable of equipping the force so that it is always ready to meet the threat with the communications capability that the warfighter demands.

The solution is not to streamline the acquisition of current C4 architecture systems, but rather to transform the acquisition process itself. There is some evidence that this paradigm shift has begun. The U.S. Navy has launched an Open Architecture (OA) initiative for rapid technology insertion of both software and hardware for shipboard applications.[3] There are some significant institutional and cultural obstacles to overcome in order to change the competitive process between very large and very small vendors, but OA could greatly reduce the time to insert new technologies on standard platforms.

Another approach is the Advanced Concepts Technology Demonstration (ACTD)[4] process, in which combatant commanders can play an active role in the demonstration and selection of new technologies. An ACTD can significantly reduce the time to introduce mature technologies. However, ACTDs still require a two- to four-year timeframe, one to two capability cycles. Blue Force Tracker had to be fielded within nine months.

In 2004, the Navy proposed a new path toward Technology Acquisition Reform, with six recommendations to enable rapid technology insertions:[5]

1. Institutionalize a Rapid Technology Acquisition Team to bypass the more deliberate acquisition process;
2. Create a Direct Reporting Program Office for Disruptive Technology to incubate transformational technologies until mature and then linked to existing programs;
3. Assign science and technology projects to acquisition advocates outside of specific applications, then assign the technology to specific customers;
4. Use well-managed risk to improve customer confidence in new technologies;
5. Redefine the test and evaluation process to complement evolutionary acquisition and spiral development;
6. Establish a technology knowledge base to improve identification of candidates for technology insertion.

These recommendations have already been promulgated for a full range of hardware and software technologies. It can be assumed that some of those technologies will be applicable to next-generation networks and C4 systems. These Navy recommendations will be reflected in the general guidelines recommended in the next two pages.

If the DoD expects NCW to experience the same unbridled, exponential growth as the commercial applications and expects to maintain the qualitative edge in C4, its transformational concepts and programs cannot afford to be tethered to the deliberate nature of current methods.

On the other hand, if the DoD is to make a convincing argument for acquisition quasi-independence, it must include rigorous internal control by a core of professionals, who provide oversight and executive privilege to halt any program or technology that seems suspiciously out of bounds. Some relaxation by Congress on aspects that hinder rapid technology insertion will be required if DoD C4 is to grow in parallel with its commercial counterparts. This will be difficult; Congress is not likely to relinquish much of its oversight authority. However, there is a model in how Congress regulates private industry. Legislative tools are applied to commercial applications when issues of safety, ethics, and monopoly come into play, but they are far less restrictive in comparison to acquisition law and regulations as applied to the DoD. However, the military-industrial complex should not be immune to severe consequences if it should take undue advantage of this proposed relaxation. National defense superiority and survival are at stake, there is no room for corruption or profiteering.

While it is beyond the scope of this study to describe a "new" acquisition model, certain general guidelines can be recommended.

Change the cultural viewpoint. The new view is that there is only one network, and it is extended to the warfighter whether in garrison or on the battlefield. The extension in itself, by whatever means, does not initiate a new program. Soldiers deployed from their installations are not unlike commercial-sector "warriors" who are engaged in fierce competition armed with wireless laptops, Blackberries®, and Palm Pilots®. Their enterprises configure commercial network hardware for mobility. The DoD enterprise should be capable of doing the same. Extending the network to the warfighter is an issue of IT configuration management and architectural conformity, but not a decades-long, weapon-system-like acquisition.

Make the GIG the moderator. For network architecture, the GIG should become the moderator of the network and all subordinate networks. It is the overarching C4 architectural framework. It would define an OA friendly environment for "street legal" systems that obey the rules of the road. The GIG management would set the rules of the road, and they would be empowered to halt the progress of backyard mechanics who try to run non-compliant platforms on the network. Further, it should be empowered to prevent immature systems from getting into a battlefield platform. As such, the GIG management becomes the internal inspector general with the unfettered ability to blow the whistle on any emerging military C4 system that is not in compliance with GIG specifications.

Harness technology to shorten decision times. Just as near-real-time situational awareness helps to shorten battlefield decision cycles, awareness of the state of technology, and near-immediate awareness of the ramifications of that technology can shorten acquisition cycles. This will require technologies to facilitate fielding, robust monitoring of the civilian market, a clear, non-technical vision statement promulgated throughout the force, and the ability to use computer simulation to predict the second and third order effects throughout the DOTLM-PF domains. First and foremost, a complete, integrated tool suite must be developed for automating as much of the fielding process as possible. This tool suite must integrate all phases of the force management process. Second, given the rapid expansion of technological capability, future processes must include the requirement

to constantly monitor the civilian market, centers of technological excellence—at home and abroad—and various technology incubators throughout the country. This requirement has a strong intelligence and interagency component. It is the size and scope of such a monitoring effort that drives the third requirement. Every soldier, sailor, airman, marine, and DoD civilian must be aware of the vision. The modern workforce is remarkably "tech-savvy;" the future workforce will be more so. They will provide not only another set of eyes, but another viewpoint—the viewpoint of the technology customer. Finally, simulations must bring instant awareness of the cost, in time, money, and impacts throughout the DOTLM-PF domains. The granularity and fidelity of this awareness should be derived from the tool suite to facilitate fielding discussed above.

Accelerate the MTOE process. The normal MTOE revision process was too slow for JNN. The brute force method used to bypass the typical two-year update process was successful, but this method is not well-suited for the immensity, complexity, and frequency of WIN-T and FCS spirals. FCS spirals are projected to persist well into the 2020's. Unless the process is changed, the eighty-five new platforms envisioned for WIN-T will choke the current MTOE revision process for the foreseeable future. The task to accelerate the MTOE process rests squarely with the U.S. Army Force Management Support Agency.

Adjust the level of the routine. Enhancing the GIG at any particular node or along any particular route should not require an acquisition process. It must be considered routine, the normal price of doing business. It helps to remember the provenance of the term "grid," which derives from the electric power grid. In this instance, power is knowledge. Our efforts to maintain the edge in combat effectiveness by keeping the systems updated and in good repair should not be considered as extraordinary events. They are merely our efforts to maintain the grid.

Accelerate the force management process. It is imperative that the decision cycle times for force management match the accelerated expectations of commanders in the field. The warfighters' accelerated expectations for C4 are inextricably tied to the short capability cycle times that are inherent in a two-year technology cycle. The cycles will inevitably become shorter in the future as Moore's Law runs its course. Thus the force management process must dynamically adjust as senior warfighters continually "re-vision" future C4 systems. Decision-making, conceptual development, and force integration and resoucing functions are all part of the force management process. A sustainable vision cannot allow the process tail to wag the dog.

Prudens Futuri

9. Conclusion

The most pathetic person in the world is someone who has sight, but has no vision.[1]

—Helen Keller
American Author and Educator

This volume, "Command, Control, Communications, and Computer Architectures," is not and could not have been an all-inclusive compendium of the full suite of equipment and personnel that makes modern battlefield communications the marvel it is today and will be in future.

Despite the shortfalls that were noted during Operation Iraqi Freedom, there were many physical and technical hurdles that were overcome to provide battlefield commanders with the voice, video, and data communications that enabled the startling speed and devastating effectiveness of that operation.

It can be said that modern society takes for granted all that is possible with little or no understanding of the technology that is masked by the box that contains it. Little if any thought is given to how these near-miracles happen or the history of their invention. Thomas Edison's description of genius as "one percent inspiration and ninety-nine percent perspiration" still applies a century later. Inventing the future is hard work. Correspondingly, the complexity of orchestrating the modern communication architectures of today is equally hard work, almost daunting. Criticisms that may have been contained in this volume are meant only to portray the hard work that is yet to be done, not diminish the efforts of those who have given their professional service to creating the incredible communications systems that exist today.

NCW Need #1

Recognize that there is a need for a more rapid C4 development program.

To that end, this volume first provided a historical view of military communications since WWII and then noted the advent of the computer as a paradigm shift that enabled the network. It also highlighted that change is exponentially increasing; that is, the rate of change itself in increasing. This function was portrayed by S-curve model. Two lessons drawn from studying the S-curve are that 1) change should be anticipated and, 2) at some point along the curve, a paradigm shift will occur that will initiate the start of a new S-curve. Not only must we learn to adapt to these changes in step with the S-curve, but our anticipation and expectation of future change has accelerated in concert with it. We have in fact begun to invent that future we are predicting, but our current force management process is retarding the efforts to achieve our vision.

The emergence of the network and the notion of NCW in the 1990s was the disruptive technology for battlefield communications. Perhaps the most significant lesson to be learned in this narrative is that there is no status quo. It follows that faster, smaller, and lighter technological advances are inevitabilities. But it should also be apparent that it is as difficult to predict the timing of the paradigm shifts, the "knee" of the S-curve, as it was difficult to predict the almost spontaneous eruption of the Internet and the World Wide Web. Concomitantly, it was virtually impossible to

predict the severe shortfall in bandwidth for military communications until it was upon us. The onslaught of multitude new C4 system architectures and their complexity required a Framework for building and integrating new architectures. The Framework would provide standards for the eventual need to share an enormous volume of data and construct collaborative tools.

The effect of the explosive demand for battlefield bandwidth was to render existing tactical communication systems obsolete, resulting in a significant shortfall in the ability to support battlefield command and control. The rapid assembly of the OIF communications architecture, as compared to the pre-OIF architecture exemplifies the hard work and perspiration expended to satisfy the vision of the warfighters in the short months leading up to the war. Despite the valiant efforts that yielded Blue Force Tracker and other tactical communications enhancements, like C2V and TACSAT, nothing could provide the total bandwidth needed, the collaboration tools desired, or the ability to command and control on the move deemed essential for the modern battlefield. Nor could anything satisfy the commander's accelerated expectations for C4.

Was this war the paradigm shift to Network Centric Warfare? This war probably acknowledged that there was a paradigm shift, but it also recognized that the communication tools needed to wage NCW were yet to be invented.

NCW Need #2

Reinvent the acquisition and force management processes for C4 programs.

Programs that appeared on the horizon at the dawn of NCW—WIN-T, JNN, CPOF, and the GIG—are used to illustrate, in the context of rapid change, the difficulties in coping with the pace of technological advances. This pace accelerates system obsolescence. In large part our existing acquisition system—at least in regard to C4 systems—exacerbates the problem of obsolescence. This points to the urgent need to reinvent an acquisition process that, with its current decade-long cycle times, is ill-suited for the rapid insertion of technology developing with a two-year cycle time .

This volume is necessarily incomplete. As noted, Congress essentially halted the further fielding of JNN until it receives a report from the Secretary of the Army—scheduled for 15 March 2007. Long delays were never deemed clever by SunTzu, and the fielding of JNN should not be construed as "stupid haste." In fact, JNN was overdue well before OIF was conceived; MSE bandwidth was shown to be inadequate in 1998.

NCW Need #3

Leverage the Navy Open Architecture Study for Army C4.

WIN-T, already in its eighth year since its concept phase, is now delayed an additional five years before it can field its initial operational capability. Both of these delays have occurred in the five months since work commenced on this volume in March 2006. Also since March, CPOF has become a program of record, and it is predicted that JNN will follow suit. The Navy Open Architecture Study could provide the antidote for such unacceptable political and bureaucratic delays in current C4 programs.

NCW Need #4

Establish migration plans for all C4 architectures and adhere to DoD Architecture Framework and the Global Information Grid.

The Global Information Grid is the "best of breed" for architectural standards and adherence to the Framework to date. This program is well-suited to pull together the multitude of architectures on the battlefield today. The GIG should have responsibility and executive oversight to steer all subordinate and interfacing architectures that expect to transport data to and from the battlefield. Trust in the GIG management should relax the burden of the present acquisition process on the subordinate

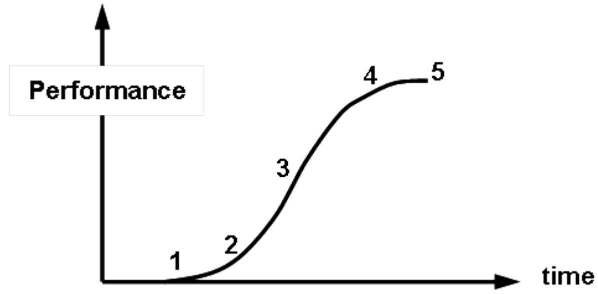


Figure 32. Technology Phases along an S-curve.

DoD architectures. There is but one network for the battlefield. Its components must be managed cohesively and unilaterally. Fragmented and parochial component program governance runs contrary to the oneness of the network. To do otherwise is to build a Tower of Babel,[2] and only serves to undermine progress towards a cohesive network and a C4 lingua franca.

Consequently, there is no closure to the view of communications architecture set forth here. Rather, it can only be said that at the dawn of NCW, the field is wide open for inventing the future. The reason is simple. If one accepts the premise that NCW is indeed another paradigm in the long history of warfare, then it is useful to once again observe the S-curve diagram at figure 32 and ponder where we might be presently on the curve. Phase 1 (rupture) occurred in the late 1990's with the recognition of the explosive growth of the Internet observed in figure 28 (Chapter 6). Phase 2 (early development) pinpoints where NCW is today. Its trial by fire in OIF was a valid test of its current state and a tempting foretaste of what it could become, if allowed to grow. Call this phase the dawn of NCW. We have seen its light and can envision a brighter day ahead. The extent and pace of the remaining phases along the curve will be determined by our response to the challenges identified in the thematic points made at the start of each chapter: 1) invention, 2) simplicity, 3) the Army you have, 4) innovation, 5) acquisition cycle times, 6) delays, 7) vision, and 8) cleverness. But our conclusion does not end here.

It is insufficient to develop C4 architectures for their own sake and at a pace that waxes and wanes with the vagaries of political and budgetary climates. The U.S. military must actually be prepared for war whenever called upon to "go to war with the army you have." The force management requirements inherent in the Army's Constitutional Title 10 responsibilities demand that capability cycle times match that of any adversarial threat. Yet it has been shown that bandwidth capability was critically lacking for any Army division by 2002 and that organic MTOE communications equipment was obsolete for the prosecution of OIF-1.

Thus, it comes down to the accelerated expectations for this new era of NCW and the ability to match these expectations with a complimentary acquisition process that will generate capability within the cycle times of the adversary. Failure to do so creates a window of opportunity for any potential adversary (see figure 33). If we accept that the U.S. program of record cycle time is ten years and that the current off-the-shelf technology cycle (available to modern adversaries) is two

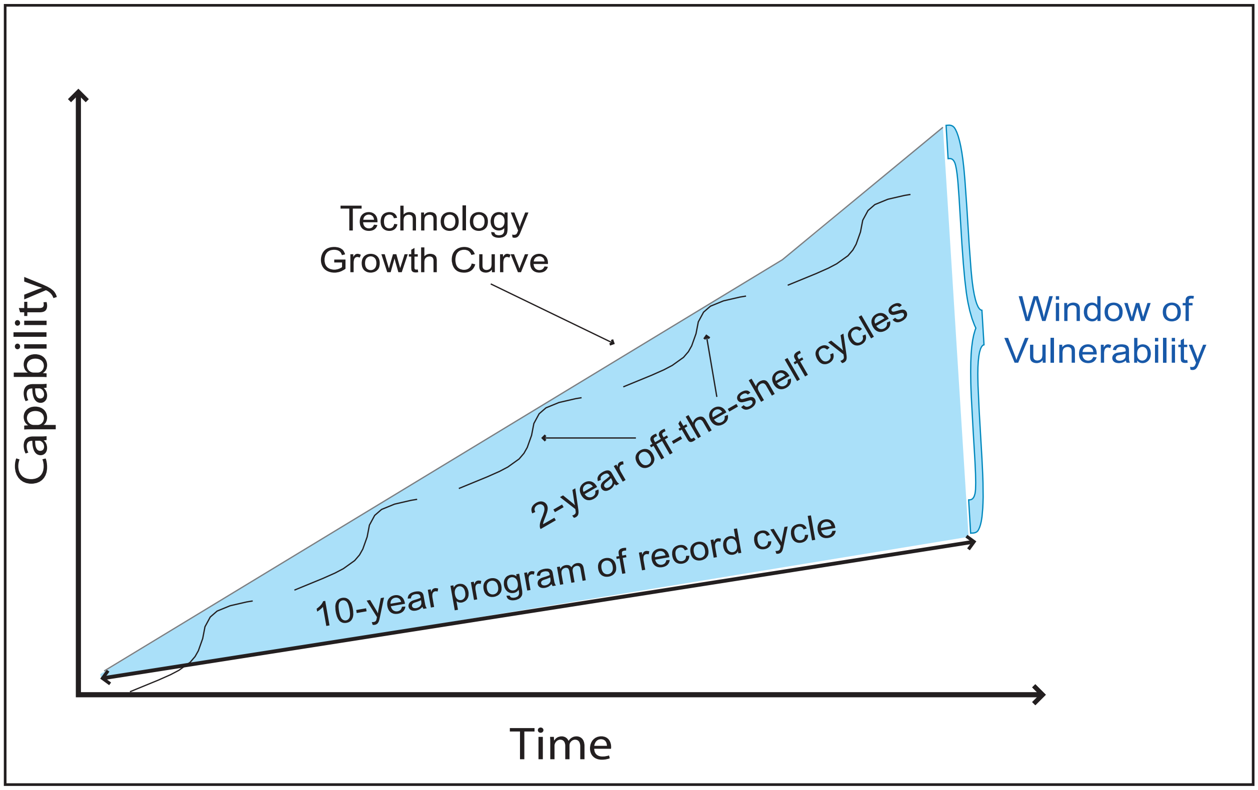


Figure 33. Off-the-Shelf Technology Versus a Program of Record Capability Cycle

years, then we must accept that *our enemy's cleverness could outmatch U.S. vision by a ratio of five to one.*

When tactical C4 programs are stripped of stringent acquisition regulations and look more like the installation and industry IT off-the-shelf, 2-year cycle model for network management, then communication architectures can be built to match, in near-real-time, commanders' expectations and vision for NCW. Creation of that future awaits invention. It is time to be clever and avoid delays.

Notes

Chapter 1: C3—Command and Control Communications before Computers

1 Department of the Army, *Field Manual 3-0, Operations* (Washington, DC: Department of the Army, June 2001), para 4-77. Battlespace is defined as "the environment, actors, and conditions commanders must understand to successfully apply combat power, protect the force, or complete the mission. This includes the air, land, sea, space, and the included enemy and friendly forces, facilities, weather terrain, the electromagnetic spectrum, and the information environment within the operational areas and areas of Interest."

2 Extending Moore's Law. Found at National Nanotechnology Initiative website, "Nanotech Facts," http://www.nano.gov/html/facts/Moore's_Law.htm

3 The term "accelerated expectations" encapsulates the notion that there is a growing impatience with the response time to our actions. The term appears in a variety disciplines. An excellent book about this phenomenon is written by James Gleik, *Faster: The Acceleration of Just about Everything* (New York: Vintage Books, 2000).

4 IBM 701 (IBM Archives website), found at "Exhibits" page http://www-03.ibm.com/ibm/history/exhibits/701/701_intro.html

5 Dilys Winegard and Atsushi Akera, "A Short History of the Second American Revolution," *University of Pennsylvania Almanac*, v. 42, n. 18, January 30, 1996, p. 6. Found at http://www.upenn.edu/almanac/v42/n18/eniac.html "While many military projects were terminated at the end of the war, ENIAC was not among them. The military's interest in high-speed computing and its use in the nuclear weapons development program ensured the Federal government's continued support of the nascent technology. At the same time, the computer's value for applications far different from problems associated with military weapons and national security came to be recognized by the military and others. A press release issued by the War Department on the occasion of ENIAC's dedication described "The Uses of Computers in Industry," with the computer seen as a means of accelerating economic growth and establishing civilian industries after a devastating war. Commercial uses for computing started to be introduced within a decade of ENIAC's development. Computer technology soon matured into a civilian industry whose growth has been astounding.

6 "Where a calculator on the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1,000 vacuum tubes and perhaps weigh 1.5 tons." This famous quote is attributed to Popular Mechanics, March 1949.

7 Co-author K. Cogan retired after 30 years commissioned service in the U.S. Army Signal Corps and Acquisition Corps (Certified Level III). During his first ten years of service in the 1970s, he was a signal platoon leader for 3d Infantry Division's main headquarters and a company commander for the V Corps' main headquarters, both located in Germany. The references to tactical communications equipment and employment in this chapter are based on his first-hand knowledge and experience, including five REFORGER exercises and numerous other maneuvers.

8 Department of the Army, *Field Manual 100-5, Operations* (Washington, DC: Department of the Army, June 1993), p. 2-15. "Reliable communications are central both to battle command and to control. General Omar Bradley once said, 'Congress can make a general, but only communications can make him a commander.' Effective battle command requires reliable signal support systems to enable the commander to conduct operations at varying operational tempos."

9 Internet protocols were first developed in the mid-1970s, when the Defense Advanced Research Projects Agency (DARPA) became interested in establishing a packet-switched network that would facilitate communication between dissimilar computer systems at research institutions. With the goal of heterogeneous connectivity in mind, DARPA funded research by Stanford University and Bolt, Beranek, and Newman (BBN). The result of this development effort was the Internet protocol suite, completed in the late 1970s. TCP/IP later was included with Berkeley Software Distribution (BSD) UNIX and has since become the foundation on which the Internet and the World Wide Web (WWW) are based. An excellent reference to the above is a robust compendium of protocols can be found on the "Documentation" page of the "Cisco" website, http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/ip.htm

10 Indeed, the Internet was created by the Department of Defense's Advanced Research Projects Agency (DARPA) to link computers at Stanford, UCLA, UC Santa Barbara, and the University of Utah so that artificial intelligence researchers at these sites could collaborate on projects funded by the military. "DARPAnet," as the resulting network was called, ensured the safe transport of data between mainframe computers at different strategic locations by creating alternate communication routes in case of bomb attack and by decentralizing functions so that no single computer could be targeted. The Internet and The WWW: A History And Introduction (University at Albany website), found at the "Learning Technology Library" page, http://www.albany.edu/ltl/using/history.html

11 "There is no reason anyone would want a computer in their home." 1977 quote attributed to K. Olsen (Founder and President, Digital Equipment Corporation),

12 FORTRAN (an acronym for FORmula TRANslation) actually dated back to the early 1950's to write scientific equations for the computer in a high order language other than 1's and 0's, whereas Pascal, named for the French mathematician Blaise Pascal had its origin in 1970 and became widespread during the introduction of the personal computer of the 1980's.

13 Later, addresses for the Internet would be known as Internet Protocol (IP) addresses.

14 Indeed, this would be the DoD expectation. The 2001 Quadrennial Defense Review would state "During the Cold War, U.S. government programs were the primary impetus for research into new technologies, particularly in areas such as computers and materials. Today and well into the foreseeable future, however, DoD will rely on the private sector to provide much of the leadership in developing new technologies." Quadrennial Defense Review Report (Washington, DC: U.S. Department of Defense, September 30, 2001), p.41.

Chapter 2: A Methodological Model for C4 Architectures

1 "Samuel F. B. Morse conceived of an electromagnetic telegraph in 1832 and constructed an experimental version in 1835. He did not construct a truly practical system until 1844, when he built a line from Baltimore to Washington, DC Within ten years after the first telegraph line opened, 23,000 miles of wire crisscrossed the country. The invention profoundly affected the development of the West, made railroad travel safer, and allowed businessmen to conduct their operations more profitably." "American Inventors and Inventions "page" of the Smithsonian Institute's Remembering Gallery website, found at: http://www.150.si.edu/150trav/remember/r819.htm

2 Author's Note: At the speed of light (186,000 miles per second) terrestrial based communications could theoretically circumnavigate the globe 7 times in one second, but this would serve no practical use. Rather it is more useful to comprehend that no two points on earth are further than 13,000 miles apart and therefore can communicate with one another in about one-third of a second or 300 milliseconds. This gives rise to the so called anthropomorphic principle. Given that our human biological senses respond at approximately 300

millisecond to stimuli, then the speed of light, the size of the earth, and human biology are a near perfect match for a most efficient human-to-human communications system when using the limits of the electronic communications. Attributed to James Martin, University of Oxford, United Kingdom.

3 James L. Crowley, *Cognitive Vision Research Roadmap* (draft vers. 2.5), found at the "euCognition" website: http://www.eucognition.org/ecvision/research_planning/ECVisionRoadMapv2.5.pdf

4 Matthew G. Richards, Nirav B. Shah, Daniel E. Hastings, and Donna H. Rhodes, *Managing Complexity with the Department of Defense Architecture Framework,* p. 3. Found at the Massachusetts Institute of Technology's Lean Aerospace Initiatives webpage http://lean.mit.edu/index.php?option=com_docman&task=doc_view&gid=1245&Itemid=88

5 USD(A&T), ASD(C3), JS/J6 Memorandum, Subject: "DoD Architecture Coordination Council (ACC)," 14 January 1997. "The Defense Science Board and other major studies have concluded that one of the key means for ensuring interoperable and cost effective military systems is to establish comprehensive architectural guidance for all of DoD."

6 The acronym C4ISR represents Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance. For the purpose of this study Surveillance and Reconnaissance will be omitted. The acronyms C4 and C4SR will be used interchangeably.

7 IEEE Standard 610.12 as found modified in the C4ISR Architecture Working Group, *C4ISR Architecture Framework Study,* (Washington, DC: U.S. Department of Defense, 18 December 1997), p. 15.

8 DoD Architecture Working Group, *DoD Architecture Framework* study, (Washington, DC: U.S. Department of Defense, 9 February, 2004), vol 1. pp. 2-4. A complete copy of the DoD Architecture Framework Deskbook can be found at http://www.defenselink.mil/nii/doc/DoDAF_v1_Deskbook.pdf

9 Mary Bellis, The History of Rubik's Cube and Inventor Erno Rubik (About.Com website) found at the "Inventors" page: http://inventors.about.com/od/rstartinventions/a/Rubik_Cube.htm

10 Hans Binnendijk, *Transforming America's Military* (Washington, DC: NDU Press, 2002), p. 41f. "private-sector sources are largely responsible for maintaining these high investment levels, public agencies such as the Department of Defense have not been able to control or direct the rapidly emerging capabilities resulting from this growth. Thus, the future, when DOD will depend on private sector investment in information technology for advances, may be very different than the Cold War, when it was DOD that financed so much basic research with military implications."

11 Ibid., p. 38.

12 Ibid., p. 44.

13 Ray Kurzweil is a noted author, inventor and recipient of the U.S. National Medal of Technology. An explanation of the Law of Accelerated Returns can be found at http://www.kurzweilai.net/articles/art0610.html?printable=1. The complete work is found at http://www.kurzweilai.net/meme/frame.html?main=/articles/art0134.html .

14 Marc Rogers, Major General, U.S. Air Force, as quoted by Jim Saxton, Member of Congress, "C4I Interoperability for Our Warfighters," *Military Information Technology,* 7 iss. 10 (December 31, 2003). The online edition version may be found at http://www.military-information-technology.com/article.cfm?DocID=348 .

Chapter 3: Pre-OIF C4 Architecture

1 United States Army Signal School, “Army Transformation and Signal Operations in the IBCT.” Briefing provided to the United States Army Signal Captains’ Career Course, January 2001.

2 United States Army Signal School, “The Brigade Combat Team: A Signal Perspective.” Briefing provided to the United States Army Signal Captains’ Career Course, January 2001.

3 William Perry (Secretary of Defense), briefing to the United States Senate Armed Services Committee, Washington DC, March 14, 1995; as cited in a briefing by the Army Transformation Panel; Institute for Land Warfare, “Soldiers On Point for the Nation: Army Transformation,” 17 October 2000.

4 William W. Hartzog, General, U.S. Army, and James G. Diehl, Lieutenant Colonel, U.S. Army, “Building the 21st-Century Heavy Division,“ Military Review, March-April 1998.

5 Eric K. Shinseki, General, U.S. Army. “The Army Transformation: A Historic Opportunity,” 2001-02 Army Green Book (Association of the United States Army, Arlington, VA, 2001). This briefing was originally given by General Shinseki as a DoD report to Congress in 1999, when Shinseki was the Chief of Staff of the Army.

6 Donald E. Fowler, Lieutenant Colonel, U.S. Army. “The 141st Signal Battalion Experience in Operations Desert Shield and Desert Storm: Combat Was Different from Training and Doctrine.” Study Project (United States Army War College, Carlisle PA, 1993). 15, 29.

7 “Army Battle Command System: Transformation Network Centric Warfare,” Capstone Requirements Document (Ft. Leavenworth, KS: Combined Arms Center, 30 June 1999)

8 Department of the Army, Army Regulation 71-32 Force Development and Documentation-Consolidated Policies (Headquarters, United States Army, Washington DC, 1997).

9 JNN has been fielded to eight of the ten active component divisions. Congressional oversight committees have halted the fielding of JNN to the last two divisions along with the reserve components awaiting hearings on funding cycles and interoperability and questions over the operational tests of the system. The next round of Congressional hearings is expected to take place during the spring of 2007.

Chapter 4: C4 Architecture During OIF-1

1 Jeffrey G. Smith, Jr., V CORPS White Paper: Battle Command Concept, Derived from the Experiences of Operation Iraqi Freedom. (U.S. Army V Corps, Heidelberg, Germany, nd). p. 11.

2 Charles Kirkpatrick, V Corps in the Combat Phase of Operation Iraqi Freedom: Some Notes and a Summary (U.S. Army V Corps, Heidelberg, Germany, 26 March 2004). p. 2. Dr. Kirkpatrick is the V Corps Historian. Report also availbable at http://www.vcorps.army.mil/History/V_Corps_condensed_history_OIF-combat_phase.pdf

3 3rd Infantry Division, Operation Freedom: Third Infantry Division (Mechanized) “Rock of the Marne” after Action Report, Final Draft, (U.S. Army, 3rd Infantry Division (Mechanized), Ft. Stewart, GA, 2003), Operational Overview, p. xiii, Battle for As Samawah: 22-24 March.

4 Interview with Major General Dennis C. Moran former CENTCOM J6 and current Vice Director for Command, Control, Communications, and Computer Systems (J6). Interview by Dave Cammons, Colonel, U.S. Army, Retired, Dennis Murphy, Colonel, U.S. Army, Retired, and Raymond G. De Lucio, Captain, U.S. Army. Raymond G. Videotaped interview 12 December, 2005. Page 9 of the transcribed interview.

5 Jeffrey G. Smith, Jr., Colonel, U.S. Army, *White Paper, Battle Command Concept, Derived from the Experiences of Operation Iraqi Freedom* (Heidelberg, Germany: V Corps G-6, 2003): p. 17. The quote is attributed to Colonel William Pope, Director of the Corps Network Operations and Security Center for Operation Iraqi Freedom, 1 June, 2003, Victory Base, Baghdad, Iraq.

6 Ibid.

7 Ibid. The quote is attributed to LTG Wallace, V Corps Commander, 13 June 2003, Camp Victory, Baghdad, Iraq.

8 Harry D. Raduege, Jr. Lieutenant General, USAF). Briefing to the National Defense Industrial Association, McLean, Virginia, February 19, 2004; as cited in Pawlikowski, Ellen M. (Brigadier General, USAF), “Military Satellite Communications: Global Network Power” (briefing, The National Contract Management Association, Los Angeles, California, December 6, 2005) also available at http://www.ncmalasb.org/Presentations/2005/December.

9 V CORPS White Paper: Battle Command Concept, p.17. The quote is attributed to LTG Wallace, V Corps Commander, 13 June 2003, Camp Victory, Baghdad, Iraq.

10 Tunneling is the transmission of data intended for use only within one network through another network. It is generally done by encapsulating the NIPRnet or non-secure network transmissions to travel over the SIPRnet, which is a secure network. The data and protocol information of the NIPRnet are set so that the non-secure network transmissions appear to the secure network as data. Tunneling allows the use of the SIPRnet which is classified, to convey data on behalf of the NIPRnet, which is an unclassified network.

11 The TACLANE (KG-175) is short for Tactical FASTLANE ® and was developed by the National Security Agency (NSA) to provide network communications security over legacy networks such as MSE packet network and SIPRnet on Internet Protocol (IP) and Asynchronous Transfer Mode (ATM) networks for users at the same security level. The KG-175 is Type 1 in-line network encryptor for DoD tactical and strategic networks.

12 From the author’s (R. De Lucio) instructional notes taken from the IDNX Planning and Engineering–JTF Systems course; Promina multiplexers manage a network’s bandwidth. Depending on the user traffic type, a Promina can apply dynamic bandwidth allocation, frame relay switching, IP routing, ISDN signaling, or voice compression, to maximize available bandwidth and minimize delay across a backbone network. They are characterized by their ability to support a broad range of user interfaces and network services. A single Promina platform can provide multiple analog and digital interfaces to localized private branch exchanges, local area networks, routers, front end processors and video sources. Originating traffic can be passed across a broad range of network or private transport services.

13 V CORPS White Paper: Battle Command Concept. Taken from the Tactical Command and Control Transformation Brief, 13 June 2003.

14 Scott R. Gourley “Marines Coordinate Joint Service and Multinational C4I Capabilities”. Military Information Technology Online Archives vol: 8 iss: 3 (May 01, 2004): p. 3. Available at http://www.mimlitary-information-technology.com/article.cfm Volume 8, Issue 3.

15 Interview with Major General Buford Blount, Commander, 3rd Infantry Division (Mechanized). Interview by John B. Tisserand III, Colonel, U.S. Army, Retired and Duane E. Williams, Colonel, U.S. Army, Retired. Videotaped interview, 19 August 2004.

16 Interview with Brigadier General Charles W. Fletcher Jr., Commander, 3rd Corps Support Command (COSCOM) During Operation Iraqi Freedom, Mar- May 2003. Interview by John B. Tisserand III, Colonel,

U.S. Army, Retired and Duane E. Williams, Colonel, U.S. Army, Retired. Videotaped interview, 20 August 2004.

18 V Corps White Paper: Battle Command Concept, p. 6.

19 3 ID, Operation Iraqi Freedom After Action Report, Operational Overview, p. 124-5.

20 From the Hackers' Dictionary of Computer Jargon, (http://www.worldwideschool.org/library/books/tech/computers/TheHackersDictionaryofComputerJargon/chap0.html) "kluged" is defined as "a clever programming trick intended to solve a particular nasty case in an expedient, if not clear, manner. Often used to repair bugs. Often involves (ad-hockery) and verges on being a (crock)."

21 V Corps White Paper: Battle Command Concept, p. 27.

Chapter 5: C4 Programs of Record in the Wake of OIF

1 David H. Gurney, Colonel, USMC, Retired, and Jeffrey D. Smotherman, "An Interview with Acting Director, DoD Office of Force Transformation, Terry J. Pudas, Joint Force Quarterly, iss. 42, (3d quarter 2006): p.34.

2 Jeremiah Jette, First Lieutenant, U.S. Army, "Warfighter Information Network-Terrestrial (WIN-T)," briefing given at Ft. Gordon, GA, 9 March 2000. All of the Figures in this chapter are taken from this briefing that was used in the Signal Captains Career Course at the U.S. Army Signal School, Ft. Gordon, GA.

3 During the 6 month research and writing of this report (Mar-Aug 2006), the WIN-T program slipped from fielding in 2008 to 2013—a full five year slip.

4 This calculation is merely an estimate by the author based on ten years divided by 18 months assumed under Moore's Law, which presumes a doubling of transistors on a chip during those months. In fact, major computer chip manufacturers will announce five successive new chip advances in a ten year period. An interesting history of the microprocessor which bears this out can be found on the PCMechanic website at http://www.pcmech.com/show/processors/35/1/ .

5 A civilian example of pending obsolescence is long distance telephony as known historically. The network has enabled new long distance telephone paradigms, notably Voice over Internet Protocol (VoIP). This disruptive technology allows internet users a voice capability via the packet switch network for free or for a fraction of long distance carrier rates. Consequently, traditional long distance companies fear the advent of VoIP and have begun to shift marketing strategies so as not to lose market share.

Chapter 6: Un-Programmed C4 Architectures in the Wake of OIF

1 Senate Bill, S.2766, National Defense Authorization Act for Fiscal Year 2007, Subtitle B—Army Programs, Sec. 111, Limitation on the availability of funds for the Joint Network Node. The report is due 15 Mar 07. The House of Representatives has similar wording in H.R.5122, Sec. 114.

2 Statement by LTG William S. Wallace, Commanding General, Combined Arms Center, U.S. Army Training and Doctrine Command, before the House Armed Services Committee on C4I Interoperability: New Challenges in 21st Century Warfare, Oct 21, 2003.

3 Colonel Smith, 22d Signal Brigade commander during OIF, gave a similar account of the extreme difficulty of providing a viable C4 capability for OIF. Interview with Colonel Jeffrey Smith, 22d Signal Brigade

commander during OIF. Interview by Kevin Cogan, Colonel, U.S. Army, Retired. Personal interview at the U.S. Army War College, Carlisle, PA. on 23 June, 2006.

4 Frank Tiboni, "Battlefield Communications: Joint Network Node Gives Soldiers Voice, Video and Data in Mobile Unit," *Federal Computer Week* (14 March 2005). Some component model numbers have changed since this article to take advantage of technology upgrades in the follow-on unit rotations.

5 The term "cheap" is relative. But given that a division could be JNN equipped for under $100 million, $1 billion is relatively cheap to fix the bandwidth problem of a ten division Army.

6 A well-written history of this conversion can be found in Byron G. Johnson, Captain, U.S. Army, "JNN: Reorganizing to Bridge the Gaps in Communication," *Army Communicator*, 30, no. 3 (Summer 2005): p. 2.

7 Based on author's personal interview with Mr. Glenn Davis, MTOE Division, U.S. Army Signal Center, Ft. Gordon, GA, 21 April 2006.

8 Based on the author's proprietary study for FCS, which strongly recommended an overhaul of the TOE process in order to accept the frequent system spinouts envisioned for the Future Force.

9 Charmain Z. Brackett, "JNN Unveiled at Gordon," *Army Communicator,* 30, no. 4 (Fall 2005): p24.

10 Co-author K. Cogan did both, first at General Dynamic's Taunton, MA facility on 10 Jul 2006 with a JNN terminal in an S-250 shelter, then on 24 Jul 2006 at the Army War College, Carlisle Barracks installation network operations center. The similarity between commercial equipment in JNN S-250 shelters and the installation network management office is striking.

11 The useful life of most computer automation hardware for commercial and office applications is about three years, after which either upgrade or replacement is necessary. This is usually due to the unavailability of replacement parts and to obsolescence factors attributed to Moore's Law. Most support contracts are written for three years—requiring desktop computers in the workplace to be replaced on a thee-year cycle, for example. Software is in a near-constant upgrade process in the Internet "back office," which is where organization network operations are managed. Failure to keep pace with industry cycles results in either unsupportability or unaffordable maintenance fees. Based on Mr. Cogan's experience as a chief information officer for an Army installation from 1997-2001.

12 Timothy L. Rider, "New Army Capability Extends the Reach of Battle Command," *The Monmouth Message*, (Ft. Monmouth, NJ) 63, no. 28 (14 Jul 06): p 1.

13 The TRA Reference Deskbook can be found at http://www.defenselink.mil/ddre/doc/tra_deskbook_2005.pdf

14 The Transformational Communications Satellite System is a prime example of the future of military satellite capabilities and program management. The program is shared among certain federal departments and is the result of bandwidth shortfalls noted in Desert Storm, the 11 September 2001 terrorist attack, and lessons from OIF. A comprehensive article in the Defense Industry Daily, posted 19 July 2005, can be found at http://www.defenseindustrydaily.com/2005/07/special-report-the-usas-transformational-communications-satellite-system-tsat/index.php .

15 Personal interview (Cogan) with Mr. Terry Edwards, SES, AMC Chief Information Officer. Mr. Edwards opined that JNN is already WIN-T. Further, acquisition competition for the last two division sets of JNN will "raise the bar" for JNN technology itself.

Chapter 7: Envisioning C4 Architectures for the Foreseeable Future

1 The quote is taken from http://www.quoteworld.org/quotes/6521. Father Hesburgh's biography may be found at http://www.nd.edu/aboutnd/about/history/hesburgh_bio.shtml .

2 Federal Enterprise Architecture Framework, Version 1.1, September 1999, p. 5, found at https://secure.cio.noaa.gov/hpcc/docita/files/federal_enterprise_arch_framework.pdf . A current version of the Federal Enterprise Architecture that was enacted in 2002 can be found at http://www.gcn.com/print/21_27/19835-1.html .

3 Before EA frameworks were adopted by other government organizations—and before they were required by the Office of Management and Budget (OMB)—the Department of Defense (DOD) had begun developing an overall standardized architecture framework. Since 1998, C4ISR Version 2 has been the mandated framework for development of DOD architectures and has influenced the development of several other civilian and military architecture frameworks around the world, including NATO's and the Federal Enterprise Architecture Framework (FEAF). The C4ISR Architecture Framework emerged as the DOD Architecture Framework in 2004. The DOD Architecture Framework has become mandatory for all architectures within the Department of Defense, not only for C4ISR-related architectures, but for other elements as well, such as acquisitions, logistics, and financial management. See Ann Reedy, "Frameworks Are Valuable Templates for Developing Enterprise Architectures," The Edge, Fall 2003, v. 7 n. 2. Available at http://www.mitre.org/news/the_edge/fall_03/reedy.html .

4 Quadrennial Defense Review Report (Washington, DC: U.S. Department of Defense, 1997), Section VII, Transforming U.S. Forces for the Future, found at http://www.defenselink.mil/pubs/qdr/sec7.html

5 "Global Information Grid (GIG). The globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters, policy makers, and support personnel. The GIG includes all owned and leased communications and computing systems and services, software (including applications), data, security services, and other associated services necessary to achieve Information Superiority. It also includes National Security Systems as defined in section 5142 of the Clinger-Cohen Act of 1996 (reference (b)). The GIG supports all Department of Defense, National Security, and related Intelligence Community missions and functions (strategic, operational, tactical, and business), in war and in peace. The GIG provides capabilities from all operating locations (bases, posts, camps, stations, facilities, mobile platforms, and deployed sites). The GIG provides interfaces to coalition, allied, and non-DoD users and systems." Definition from the "Department of Defense Directive Number 8100.1: Global Information Grid (GIG) Overarching Policy" (Washington DC: Department of Defense, 19 September 2002). Enclosure E, p. 8. Found at http://www.dtic.mil/whs/directives/corres/pdf/d81001_091902/d81001p.pdf .

6 The are many other GIG imperatives in the DoD Directive, 8100.1.

7 Department of Defense Chief Information Officer, Department of Defense Net-Centric Data Stategy, (Washington, DC: Department of Defense, 9 May 9 2003). Found at http://www.defenselink.mil/nii/org/cio/doc/Net-Centric-Data-Strategy-2003-05-092.pdf.

8 Quadrennial Defense Review Report (Washington, DC: U.S. Department of Defense, 30 September, 2001), Section VII, Transforming U.S. Forces for the Future, pp. 25f. Available at http://www.dtic.mil/ndia/logistics/fowler.pdf#search=%222001%20%22Quadrennial%20Defense%20Review%22%20pdf%22

9 Note: The schedule for WIN-T slipped to 2013 from 2008 during the six month period of research for this study.

10 Harold Greene, Colonel, U.S. Army, Program Manager for Battle Command Software Blocking Trail Boss, "ABCS Migration to the Future," 20 April 2006 briefing, found on the AFCEA, Ft. Monmouth Chapter Website, Briefings page, http://www.afcea-ftmonmouth.org/documents/Lunch%20briefs/2006/ABCS%20Overview%20v2.pdf

11 In testimony before the Airland Subcommittee of the Senate Armed Service Committee (Second Session, 106th Congress) on 8 March 2000, then Chief of Staff of the Army, GEN Eric K. Shinseki, outlined the tenets of The Army Vision and the road to transforming the Army. Available at http://armed-services.senate.gov/statemnt/2000/000308es.pdf

Chapter 8: Envisioning C4 Architectures for the Foreseeable Future

1 This quote is sometimes attributed to Henry Ford, but in recent times it was used in a speech by Dr. Da Hsuan Feng, Vice President for Research and Graduate Education, University of Texas (Dallas) in his welcoming speech to new faculty on 18 August 2003. Later, in a testimony to the U.S. House of Representatives Science Committee Hearing, 23 Jan 04, he used the quote again, but could not recall where he had first heard it.

2 Scott Nance, "Analyst: Advanced Networks to Be Rumsfeld Legacy," *Defense Today,* December 8, 2005: p 1.

3 See Chisholm, Patrick. "Architecture for Change," *Military Information Technology*, 10, iss. 3 (2006). Found at http://www.military-information-technology.com/print_article.cfm?DocID=1402

4 See ACTD article at http://www.defenselink.mil/execsec/adr96/chapt_11.html

5 The Navy Technology Acquisition Reform executive summary can be found on the "Reports and Executive Summaries" page of the Naval Research Advisory Committee Website at http://www.onr.navy.mil/nrac/docs/2004_es_technology_acquistion_reform.pdf

Chapter 9: Envisioning C4 Architectures for the Foreseeable Future

1 Helen Keller, American author and educator who was blind and deaf, 1880-1968.

2 According to the narrative in Genesis, Chapter 11, the Tower of Babel was a tower built in the land of Shinar that was meant to have a "top in the sky." Seeing their arrogance, God put a stop to the process by confusing their language, "so that they will not understand what another says." The builders were scattered, with many languages and many races.

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2 Gregory Slabodkin, "Faxes are Low on Army's Priorities List" *GCN Home*, July 13, 1998.

3 Anthony J. Ricchiazzi, "Tactical Satellite Terminals to Get New Lease on Life," *Army Communicator,* Fall 2003.

4 White Paper: Battle Command Concept, G-6: 44.

5 Department of the Army, *Field Manual 6-02.45 Technical Characteristics of the AN/TTC-56,* (Washington, DC: Department of the Army, 2004): D-21-2.

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Appendix A

Glossary

A2C2	Army airspace command and control
AAR	after action review
ABCS	Army Battle Command System
AC	active component
ACM	Airspace Control Measures
ACTD	Advanced Concepts Technology Demonstration
ADA	air defense artillery
ADOCS	automated deep operations coordination system
ADSI	Air Defense System Integrator
AFATDS	Advanced Field Artillery Tactical Data System
AMD	Air and Missile Defense
AMDPCS	Air and Missile Defense Planning and Control System
AMDWS	Air and Missile Defense Work Station
AO	area of operation(s)
ASC	Army Signal Command
ASAS	All-Source Analysis System
ASAS-L	All-Source Analysis System-Light
ATM	asynchronous transfer mode
ATS	Air Traffic Services
AUSA	Association of the United States Army
AUTODIN	automated defense information network
AWACS	Airborne Warning and Control System
AWE	advanced warfighting experiments
BCOTM	battle command on the move
BCT	brigade combat team
BDA	battle damage assessment
BFAs	Battlefield Functional Areas
BFT	blue force tracker
BG	brigadier general
BM/C4I	Battle Management Command, Control, Communications, Computers, and Intelligence
BOS	battlefield operating system
BTOE	base table of organization and equipment
C2	command and control

C2OTM	command and control on the move
C2PC	command and control personal computer
C2V	command and control vehicle
C3	command, control, and communications
C4	command, control, communications, and computers
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
C4SR	Command, Control, Computers, Communications, Surveillance and Reconnaissance
C-Main	corps main command post
C-Rear	corps rear command post
CAV	cavalry
CBCS	common baseline circuit switches
CFLCC	Coalition Forces Land Component Command
CG	commanding general
CHD	Conservative Heavy Division
CINC	commander in chief
CIO	Chief Information Officer
CNOSC	Coalition Network Operations and Security Center
COBOL	Common Business Oriented Language
COC	Combat Operations Center
COL	colonel
CONOPS	contingency operations
CONUS	Continental United States
COP	common operational picture
COSCOM	Corp Support Command
COTM	communications on the move
COTS	commercial off-the-shelf
CP	command post
CPG	Contingency Planning Group
CPOF	Command Post of the Future
CRD	Capstone Requirements Document
CSAR	Combat Search and Rescue System
CSL	Center for Strategic Leadership
CSSCS	combat service support control system
CTP	common tactical picture
DAMA	demand assigned multiple access

DARPA	Defense Advanced Research Projects Agency
DATM	DISA ATM network
DAWE	division advance warfighter experiment
DCTS	Defense Collaborative Tools Suite
D-Main	division main command post
D-Rear	division rear command post
D-TAC	division tactical command post
DGM	digital group multiplexer
DISN	Defense Information Systems Network
DKAT	deployable Ku-band satellite terminal
DoD	Department of Defense
DoDAF	DoD Architecture Framework
DOTML-PF	doctrine, organization, training, materiel, leader and education, personnel, and facilities
DSN	Defense Switched Network
DSRN	Defense Red Phone Switch
DTAC	division tactical command post
DTLOMS	doctrine, training, leader development, organization, materiel, and soldiers
DTMF	dual tone, multi-frequency
DTRACS	Defense transportation reporting and control system
DTSS	digital topographical support system
DVS-G	DISN Video Services Global
EAC	echelon above corps
EMT	effects management tool
ENIAC	Electronic Numerical Integrator and Computer
EPLRS	enhanced position location reporting system
FAR	Federal Acquisition Regulations
FBCB2	Force XXI Battle Command Brigade and Below
FCS	Future Combat Systems
FEAF	Federal Enterprise Architecture Framework
FECC	Fires and Effects Coordination Cell
FDD	first digitized division
FM	Frequency modulation
Force XXI	Force Twenty-One [21st century Army]
FTP	File transfer protocols
GBS	Global Broadcasting Service
GCC	Global Control Center

GCCS	Global Command and Control System
GCCS-A	Global Command and Control System-Army
GIG	Global Information Grid
GIS	Geographic Information System
GMF	ground mobile forces
GPS	global positioning system
HF	high frequency
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HTML	hypertext markup language
IA	Information Assurance
IDNX	integrated digital network exchange
IEEE	Institute for Electrical and Electronics Engineers
IEW	intelligence and electronic warfare
IMETS	Integrated Meteorological System
INMARSAT	International Maritime Satellite System
IOT&E	initial operational test and evaluation
IPB	intelligence preparation of the battle space
ISYSCON	Integrated Systems Control
IT	information technology
IWS	InfoWorkSpace
JCDB	Joint Common Database
JMNS	joint mission need statement
JMTK	joint mapping toolkit
JNN	joint network node
JROC	Joint Requirements Operational Concept
JSTARS	joint surveillance, target attack radar system
JTA	Joint Technical Architecture
JTF	Joint Task Force
JWARN	Joint Early Warning System
JWICS	Joint Worldwide Intelligence Communications System
Kbps	kilobits per second
KM	kilometer
LAN	local area network
LCC	Local Control Centers
LD	line of departure
LEN	large extension node switch
LOS	line of sight

LTC	lieutenant colonel
LTG	lieutenant general
MCS	maneuver control system
MCS-L	maneuver control system-light
MDMP	military decision-making process
MEDEVAC	medical evacuation
MEF	Marine Expeditionary Force
MILSATCOM	military satellite communications
MLRS	multiple launch rocket system
MOOTW	military operations other than war
MOUT	military operations on urbanized terrain
MSE	mobile subscriber equipment
MSRT	mobile subscriber radiotelephone terminal
MTOE	modified table of organization and equipment
MTS	mobile tracking system
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, chemical
NC	node center
NCO	network centric operations
NCW	network centric warfare
NDI	non-developmental item
NET	New equipment training
NETCOM	(Army) Network Enterprise Technology Command
NetOps	network operations
NEW	network enabled warfare
NICSMA	NATO Integrated Communications Systems Management Agency
NIPRNET	nonsecure internet protocol router network
NSFS	Naval Surface Fire Support Systems
NSS	National Security Systems
OA	Open Architecture
OEF	Operation Enduring Freedom
OFT	Office of Force Transformation
OIF	Operation Iraqi Freedom
OIF-1	OIF, phase one (maneuver phase)
OPSEC	operational security
OOTW	operations other than war
ORD	operational requirements document

OSD	Office of the Secretary of Defense
OTE	operational test and evaluation
OTM	on the move
OTOE	Objective Table of Organization and Equipment
PC	personal computer
PLI	position location information
QDR	Quadrennial Defense Review
RAU	radio access units
RC	reserve component
RCC	Regional Control Centers
RETRANS	retransmission
RF	radio frequency
ROC	required operational capability
RSC	Regional Support Centers
RSO&I	reception, staging, onward movement, and integration
RWS	remote work station
SA	situational awareness
SALUTE	size, activity, location, unit, time, equipment [SPOT report format]
SASC	Senate Armed Services Committee
SATCOM	satellite communications
SCTACSAT	single channel tactical satellite
SEN	small extension node switch
SINCGARS	Single Channel Ground and Airborne Radio System
SIPRNET	secure internet protocol router network
SLGR	small lightweight global positioning system receiver
SMART-T	secure mobile anti-jam reliable tactical terminal
SOF	special operations forces
SPC	specialist
SSI	Soldier-System Interface
SSS	single shelter switch
STAMIS	Standard Army Management Information System
STE	Secure Terminal Equipment (STU-III/STE)
STEP	standard tactical entry point
STU-III	Secure Telephone Unit
TAC	tactical command post
TACSAT	tactical satellite
TAIS	tactical airspace integration system

TCP/IP	Transmission Control Protocol and Internet Protocol
TDA	table of distribution and allowances
THSDN	tactical high speed data networks
TI	Tactical Internet
TOC	tactical operations center
TOE	table of organization and equipment
TRA	technology readiness assessments
TRADOC	Training and Doctrine Command
TRI-TAC	Tri-service Tactical Communications System
TROPO	Tropospheric scatter radio
TS/SCI	top secret/sensitive compartmented information
TTP	tactics, techniques, and procedures
UAV	unmanned aerial vehicle
UHF	ultra high frequency
UK	United Kingdom
USCENTCOM	United States Central Command
USEUCOM	United States European Command
USMC	United States Marine Corps
VHF	very high frequency
VoIP	voice over IP
VTC	video teleconference
WAN	wide area network
WIN	Warfighter Information Network
WIN-T	Warfighter Information Network -Tactical (WIN-T)

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Appendix B
Peer Reviewer

The peer review process involved a series of reviews by three independent peer reviewers. This was planned and incorporated into the study from the outset. The peer reviewer used for this study was Major General Dennis C. Moran, Vice Director for Command, Control, Communications, and Computer Systems (J6). The insights and comments provided by the Major General Moran were invaluable.

Major General Dennis C. Moran, a graduate of the University of Notre Dame, was commissioned from the Reserve Officer Training Corps and entered the U.S. Army Signal Corps in July 1976. Upon completion of the Signal Officer Basic Course, Airborne and Ranger Schools, he served as a platoon leader in the 426th Signal Battalion, 35th Signal Group. He went on to command HHC, 426th Signal Battalion from January to December of 1979.

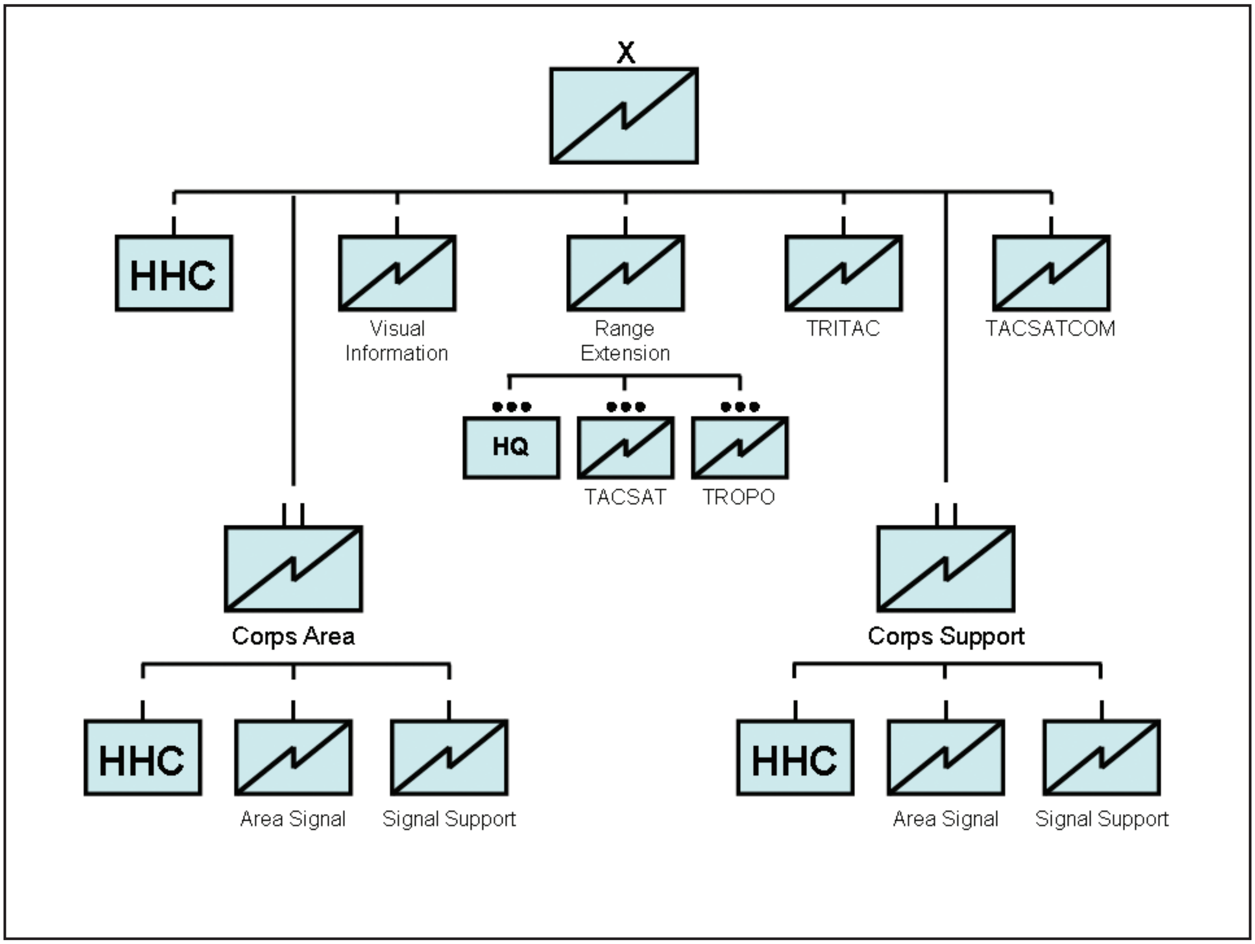
After attending the Signal Officer Advance Course and the USAF Telecommunications Staff Officers Course in Biloxi, Mississippi, he was assigned to the 123d Signal Battalion, 3rd Infantry Division in Wuerzburger, Germany. He then served as the Assistant S-2/3 and, eventually, as the S-2/3. In December 1983, he returned to Fort Gordon and served as a project officer in the Directorate of Combat Developments. He became the Chief of Transmission Systems Branch, working such projects as Tactical Satellite, SINCGARS, Improved High Frequency Radio, and the family of Digital Group Multiplexer equipment.

Major General Moran graduated from the Command and General Staff College in 1987. He was then assigned to SHAPE Headquarters in Mons, Belgium and served as the Executive Officer to the Deputy Controller, NATO Integrated Communications Systems Central Operating Authority. In 1990, Major General Moran was reassigned to the 93d Signal Brigade in Stuttgart, Germany and served as the Executive Officer, 51st Signal Battalion. He served in that post during Operation Desert Shield/Storm. He then went on to command the 97th Signal Battalion in Mannheim, Germany and as the Deputy Brigade Commander, 22d Signal Brigade, V Corps in Darmstadt, Germany. In June 1996, he graduated from the U.S. Army War College in Carlisle Barracks, Pennsylvania.

Major General Moran commanded the 3rd Signal Brigade at Fort Hood, Texas from June 1996 until June 1998. Upon completing command, he was assigned to the Defense Information Systems Agency. He then went on to command the White House Communications Agency from February 1999 until March 2000. He was then reassigned to the Defense Information Systems Agency as a Special Assistant to the Director. From June 2000 to June 2003, he served as the Director of Command and Control, Communications and Computer Systems at the United States Central Command during Operation Enduring Freedom and Operation Iraqi Freedom. He then moved to Washington D.C. in June 2004 to become the Director of Information Operations, Networks and Space for the Army Chief Information Officer/G-6. He assumed his current duties as the Vice Director for Command, Control, Communications, and Computer Systems (J6), The Joint Staff, in June 2005.

Major General Moran's awards include the Defense Superior Service Medal (w/Oak Leaf Cluster), the Legion of Merit, the Bronze Star, the Defense Meritorious Service Medal (w/oak leaf cluster) and the Army's Meritorious Service Medal (w/two oak leaf clusters). He has also earned the Presidential Service Badge.

Appendix C
Corps' Signal Unit TOE



Corps Signal Brigade

TOE 11445L100, when organized as non-airborne

Mission: To provide mobile subscriber equipment (MSE) communications system support in the corps area.

Headquarters Company

Mission:

a. Provide command, control, administrative, and logistical support for the corps signal brigade (TOE 11400l200).

b. Provide a signal staff element to advise the corps on communication, automation, and COMSEC matters.

c. Install, operate, and maintain a tactical satellite (TACSAT) system to extend the corps MSE area communications.

Signal Visual Information (VI) Company (corps)

Mission: To provide the HHC, Corps Signal Brigade (TOE 11400l200) the means to satisfy all operation and maintenance of visual information combat camera (COMCAM) facilities required to support corps and subordinate tactical command headquarters, to include VI laboratory facilities operation and support. Additionally, COMCAM provides support for digital still video base stations, and VI maintenance and repair support for organic VI equipment and functional user/unit VI equipment.

Range Extension Company

Mission: Employ long haul transmission systems to provide network connectivity between widely dispersed areas of operation/force. The range extension company is organized to perform its mission in any level of conflict. Multichannel satellite ground terminals will be employed at MSE node centers, at node management facilities, and corps and division system control center.

Tropo Platoon

Mission: Provide 4 tropospheric scatter radio terminals which provide tactical multichannel high capacity transmission systems. Troposcatter radios provide range extension up to 150 miles for multiplexed voice and data circuits. The tropo team is organized to perform its mission in any level of conflict.

TACSAT Platoon

Mission: To employ long haul transmission systems to provide network connectivity between widely dispersed areas of operation/forces.

TRITAC Company

Mission: To provide the contingency corps signal brigade the means to satisfy all contingency corps and joint services mission support requirements during a contingency operation or full corps deployment.

Signals TACSATCOM Company

Mission:

a. Provide tactical satellite communications terminal facilities at major communications switching nodes and command posts in a theater army communications system.

b. Provide command, control, administration, and logistical support for the corps signal support battalion. The headquarters company provides the following functions for the battalion: planning and supervision; religious support; Class III support, and maintenance of property book for units assigned to the battalion; direct support (DS) maintenance of organic communications-electronics and COMSEC maintenance support; and food service augmentation support for the battalion.

Corps Area Signal Battalion (MSE)

Mission: To provide a portion of the corps area MSE communications system.

Headquarters Company

Mission: To provide command and control, administrative and logistical support for the corps area signal battalion.

Area Signal Company

Mission: To install, operate, and maintain a portion of the division MSE communications system.

Signal Support Company

Mission: To provide communication facilities and personnel to augment the MSE corps area communictions system, to provide a switching center and MSE system access points for combat net radio interface (NRI) and wire subscribers.

Corps Support Battalion

Mission: To provide MSE communications system support in the corps area.

Headquarters Company

Mission: To provide command and control, and administrative and logistical support for the corps signal support battalion.

Area Signal Company

Mission: To install, operate, and maintain a portion of the division mobile subscriber equipment (MSE) communications system.

Signal Support Company

Mission: To provide communication facilities and personnel to augment the mobile subscriber equipment (MSE) corps area communications system, to provide a switching center and MSE system access points for combat net radio interface (NRI) and wire subscribers.

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Appendix D
Major MSE and DGM Components

MSE

MSE has various integrated components to ensure mobile and static subscribers have voice, data, and facsimile capabilities. These capabilities support the subscribers' communications no matter where they are in the MSE grid network of the AO. MSE major components include the following:

- Large Extension Node (LEN) Switch AN/TTC-46
- Node Center (NC) Switch AN/TTC-47
- Small Extension Node (SEN) AN/TTC-48
- Radio access unit (RAU) AN/TRC-191
- Line-of-sight (LOS) radio system (components of the switches)
- Subscriber terminals
- Mobile subscriber radiotelephone terminal (MSRT)
- Digital Non-Secure Voice Terminal (DNVT)
- Digital Secure Voice Terminal (DSVT)
- Facsimile
- User Terminals

Large Extension Node (LEN) Switch AN/TTC-46

Large Extension Node

Features :

- Two packet switches per LENS;
- Four LAN ports;
- Seven conditioned diphase X.25 ports;
- 32 trunks of 16 kbps each or two 512 kbps trunk groups between the LEN and two NCSs.

External terminations

- Digital: Trunks and local terminations;
- Analog: Commercial telephone;
- Three Digital Transmission Group (DTGs) encrypted by trunk encryption devices (TEDs);
- Two DTGs to two different NCs;
- One DTG assignable to a SEN;
- Combat Net Radio interface capability;
- 10 kW diesel generator, PU-753/M or PU-798.

Figure D-1. Large Extension Node AN/TTC-46

Node Center Switch

Features :

- One gateway packet switch per NCS;
- Two LAN ports;
- 64 trunks of 16 kbps each on the 1024 kbps trunk group between one NCS and another External terminations Digital: Trunks and local loops;
- Analog: NATO applications ;
- 16 DTGs, 15 of which are encrypted by TEDs.

Figure D-2. Node Center (NC) Switch AN/TTC-47

The Large Extension Node (LEN) Switch provides wired communications for personnel at large command posts (CPs). A LEN enables up to 164 wired subscribers to communicate freely using automatic flood search routing. Subscribers have access to the NCs and to the rest of MSE via Line of Sight (LOS) radios that connect to the LEN by cable or super high frequency radio systems. The LEN also provides automatic subscriber finding features that allow permanent subscriber address assignment and removes the requirement of knowing where the subscriber is physically located. It consists of two S-250 shelters containing a switching group and an operations group. Each shelter is mounted on an M-1097 HMMWV. The LEN is configured basically the same as the NCS. Differences include the configurations for terminating trunks. The LEN is not a tandem switch because it is not used primarily as an intermediate switching point between other switching centers. The LEN supports flood search routing. The switching group provides the external interface, circuit switching, and associated functions. The operations group provides central processing and operator interface functions. The LEN can enable CNR users to enter the MSE network and can provide access to commercial networks.

Node Center (NC) Switch AN/TTC-47

NCs provide key switching, traffic control and access points for MSE. The Division G6 determines the coverage area and NCs are allocated to establish a corps MSE grid network. NCs are primarily linked by LOS radios to provide communications throughout the system via the Node Center Switch. TACSAT and tropo are connected to the NCs by cable for extended distances. If one NC is disabled, the system automatically routes communications through another NC.

The Node Center Switch serves as an access point for LENs, SENs, RAUs, and ISYSCON systems. When fielded, the NCs will be the hub of the MSE node and provides network interface for subscriber access elements. It provides automatic subscriber finding features that allow permanent address assignment and removes the requirement of knowing where the subscriber is physically located. It is contained in three S-250 shelters: the switching group, the operations group, and the node management facility (NMF). Each shelter is mounted on an M-1097 HMMWV. The

switching group provides the external interface, circuit switching, and associated functions. The operations group provides central processing and operator interface functions.

Small Extension Node (SEN) Switch AN/TTC-48

The SEN supports the communications needs of smaller CPs. The AN/TTC-48(V1) can support 26 wired subscribers and the (V2) can support 41 subscribers. Users have access to NCs and to the rest of MSE via LOS radios that connect to the small extension node switch (SEN) by cable or SHF radio systems.

The SEN also provides automatic subscriber finding features when connected to an NCS or a LEN. These features allow permanent subscriber address assignment, and they remove the requirement of knowing where the subscriber is physically located. The SEN is in one S-250E shelter mounted on an M-1097 HMMWV. The SEN consists of switching, multiplexing, and communications security equipment. The SEN is available in two versions: (V1) and (V2). Both versions provide two commercial office interfaces and a secure digital net radio interface (SDNRI) using the SDNRI unit (SDNRIU), KY-90. The SENs can interface with the NCS and LENs directly via cable, LOS multichannel radio, or multichannel TACSAT links.

FORCE ENTRY SWITCH (FES) AN/TTC-50

The FES combines the essential functions of the NCS/LEN/NMF shelters and a RAU in one shelter. The FES combined with an LOS AN/TRC-198 comprises the contingency communications package. The connections between the FES and the LOS are by cable. The FES has packet switch capability, but it has no gateway function. Therefore, it has no direct connections to adjacent corps or EAC. The FES can be operator-controlled outside the shelter by a dismountable node management facility (DNMF) remote terminal.

The FES provides full flood search capability via the downsize routing subsystem (RSS-D), an SHF interface capability, and a DSVT in the truck. The line termination unit (LTU) provides

Small Extension Node

TPN:

- One packet switch per SENS;
- Two LAN ports;
- Five conditioned diphase X.25 ports;
- 16 trunks of 16 kbps each on the 256 kbps trunk group between the NCSs or LEN.

External terminations:

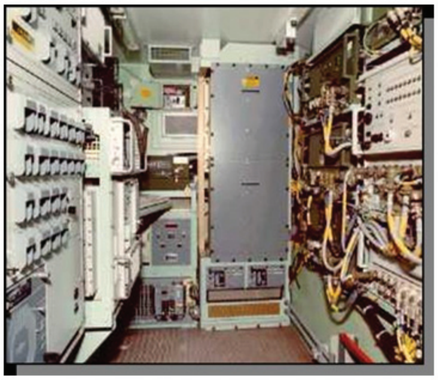
- Digital: Trunks and local terminations;
- Analog: Commercial telephone;
- Two digital switch versions:
  - Switch V1: 26 digital terminations;
  - Switch V2: 41 digital terminations.

Two small switchboards (SB-4303):

- One DTG Switch V1:12 channels to NC or LEN;
- Switch V2: 15 channels to NC or LEN;
- Two commercial drops;
- CNR interface capability;
- 10 kW diesel generator, PU-753/M.

Figure D-3. Small Extension Node Switch AN/TTC-48

Force Entry Switch



Features
:
- One packet switch;
- Ports for two LANs and six X.25 local hosts;
- One dial-in port;
- Dismounted CNR interface;
- Downsized RAU capability for up to 25 subscribers.

Figure D-4. Force Entry Switch

modem/multiplex functions for the local subscriber interface and is equipped with a rear terminal board to permit direct connections instead of the J-1077.

The LOS AN/TRC-198 is similar to an LOS(V3), except that the LOS AN/TRC-198 UHF radios operate on three separate link connections to the FES (no multiplex) and all links operate on either band.

LOS RADIO SYSTEMS AN/TRC-190

The LOS radio system consists of versatile links that connect all NCs in a grid network and provides automatic switched services to all wire and mobile subscribers. This radio grid delivers wireless communications to areas covering thousands of square kilometers. The LOS radio system, AN/TRC-190(V), has four versions.

LOS Radio, AN/TRC-190

Radio, AN/GRC-226(V) equipped with a digital group multiplexer Two NATO frequency bands:

- Band 1: 225-400 MHz
- Band 3: 1350-1850 MHz

Nominal range: 25-40 kilometers and powered by 5 kW diesel generators. The four versions are:

1. The AN/TRC-190(V1) is an LOS multichannel radio terminal. It provides point-to-point UHF radio links using the AN/GRC-226(P) radio set between various nodes of the MSE system. It can provide a short-range and a point-to-point SHF radio link. The SHF radio functions as a short-range, down-the-hill (DTH) radio providing a low signature connection between the sheltered CP site and the more exposed LOS terminal site. Each radio link supports a single, full-duplex, group-level connection and a single digital voice orderwire (DVOW) channel. The (V1) is equipped with one AB-1339 mast with Band I and Band III antennas. The planning range of the UHF radio is 40 kilometers (28 miles). The (V1) typically deploys with the SEN or remote RAU.

2. The AN/TRC-190(V2) is an LOS multichannel radio terminal. It provides point-to-point UHF radio links using the AN/GRC-226(P) radio set between various nodes of the MSE system. It can provide a short-range and a point-to-point SHF radio link. The SHF radio set operates in tandem with the primary UHF radio link. Each radio link supports a single, full-duplex, group-level connection and a single DVOW channel. The (V2) is equipped with two AN/GRC-226(P) radio sets (one on-line and one spare) and one AB-1339 mast with Band I and Band III antennas. The planning range of the UHF radio is 40 kilometers (28 miles). The (V2) typically deploys as an analog interface to NATO forces.

Figure D-5. TRC-190 antenna

3. The AN/TRC-190(V3) is an LOS multichannel radio terminal. It provides point-to-point UHF radio links using the AN/GRC-226(P) radio set between various nodes of the MSE system. It can provide a short-range and a point-to-point SHF radio link. The SHF radio set operates in tandem with the primary UHF radio link. The SHF radio functions as a short-range radio link providing connectivity for CPs. Each radio link supports a single, full-duplex, group-level connection and a single DVOW channel. The (V3) is equipped with four AN/GRC-226(P) radio sets (two on-line and one spare), and three AB-1339 masts with two Band I and two Band III antennas. The planning range of the UHF radio is 40 kilometers (28 miles). The (V3) typically deploys with the NCS and is a radio relay.
4. The AN/TRC-190(V4) is an LOS multichannel radio terminal. It provides point-to-point UHF radio links using the AN/GRC-226(P) radio set between various nodes of the MSE system. Each radio link supports a single, full-duplex, group-level connection and a single DVOW channel. If the AN/TRC-190(V4) has an AN/GRC-224(P) radio set installed, it can provide a short-range and point-to-point SHF radio link. The (V4) is equipped with two AN/GRC-226(P) radio sets (two on-line) and two AB-1339 masts with Band I and Band III antennas. The planning range of the UHF radio is 40 kilometers (28 miles). The (V4) typically deploys with the LENs.

Remote Access Unit (RAU) AN/TRC-191

The RAU picks up signals from the MSRT and sends them to the NC. When a mobile user moves out of range of one RAU and into another, the telephone service automatically transfers to the next (new) and into the range of another RAU, thus providing automatic re-affiliation. Any subsequent calls will be placed through the system via the new RAU ensuring full and continuous functional affiliation throughout the AO.

The RAU, AN/TRC-191, is a fully automatic radio interface for MSRT subscribers. The RAU connects directly to the NC by cable or remotely via LOS radio. Through the parent NC, the local RAU provides radio coverage by automatically establishing secure and full-duplex communications between the MSRT and the MSE network. The planning range between the MSRT and RAU is 15 kilometers (9.3 miles). Terrain and weather will affect the actual range.

Remote Access Unit (RAU)

Features:

- Eight digital radios, RT-1539;
- Capacity of eight simultaneous MSRT calls;
- One DTG of 256 kbps using 10 channels to NC;
- Frequency range—
  - OCONUS: 30-88 MHz;
  - CONUS:
    - 30-50 MHz;
    - 30-35 MHz low band;
    - 40-45 MHz high band;
- Full duplex (uses high band/low band concept for simultaneous transmit/ receive);
- 5 kW diesel generator, PU-751/M or PU-797.

Figure D-6. Remote Access Unit.

Integrated System Control (ISYSCON)

Integrated Systems Control (ISYSCON) provides an automated management and synchronization of multiple tactical communications and command/control systems. ISYSCON will be used at Theater, EAC, corps and division down to brigade and below. It will provide automated network management assistance for the following: Network Planning and Engineering, Battlefield Spectrum Management, Signal Command and Control, Wide Area Management, and Communications Security. In addition, ISYSCON will provide LAN management capabilities to monitor and maintain ABCS connectivity and communication services in the Tactical Operations Center.

ISYSCON enables the commander to interact with ABCS by exchanging common battle command information with the force commander and his staff and by exchanging communications information with maneuver force signal officers. ISYSCON uses common hardware and software (CHS) for its workstations. The software meets the Department Information Infrastructure (DII) common operating environment (COE) standards for information exchange. ISYSCON is a suite of hardware and software in an S-250 or a standard integrated command post system (SICPS) shelter, and it is transported by heavy HMMWVs.

ISYSCON extends to other ISYSCONs through the NC from ECB to EAC providing a complete, integrated network picture. ISYSCON will also extend to the Theater Signal Command (Army) (TSC(A)) ISYSCON and to the Joint Network Management System (JNMS). ISYSCON provides the tools to perform the information management process by automating the following functions:

- Network planning and engineering (NPE).
- Wide area network (WAN) management.
- MPM.
- Battlefield spectrum management (BSM).
- COMSEC management.

- System administration.
- Local area management (LAN).

The existing MSE SYSCON capability is housed in the SCC-2, AN/TYQ-46(V). It monitors, manages, and configures the MSE network (voice and data) for optimum communications. It has the following ISYSCON features and capabilities:

- Large-screen display.
- Digitized topographical maps.
- TPN management/planning.
- Frequency management/planning/distribution.
- Automatic updating of standby SCC-2.

The SCC-2 is an integrated, computerized communications control system that provides automated, near real-time system control to support planning, configuring, reconfiguring, and monitoring the operation and movement of MSE assets. The SCC-2 normally connects to an NCS or LENs using pulse code modulation cables.

The SCC-2 comes in two versions: (V1) and (V2). Version 1 at corps consists of three shelters: one technical and two management/planning shelters. Version 2 is a stand-alone workstation for the corps area and support signal battalions. The SCC -2 at division consists of two shelters: one technical and one management/planning.

The technical shelter contains a network management center (NMC) workstation and a technical workstation that provides a near real-time graphic display of the MSE network. The NMC monitors and controls the TPN. The primary function of the technical workstation is to monitor and to assign management functions. The network planners working inside the management/planning shelter complete the following functions:

- Deployment management.
- SCC-2 supervision and management.
- Boundaries management.
- COMSEC key management.
- Very high frequency (VHF) management.
- Ultra high frequency (UHF)/SHF management.
- Subscriber database management.
- Message management.

The management/planning shelter houses two system management workstations. These workstations provide a near real-time graphic display of the MSE network and the automated tools necessary to create and change databases required for MSE operations.

The network planning tool (NPT) with its planning and management functions supports the SCC-2. The NPT provides improved NPE and operational automated information management capabilities. The enhanced NPE and operational functions of the NPT include:

- Environmental parameters.

- Digitized mapping.
- Radio/antenna system engineering.
- Terrain analysis profiling.
- System asset placement.
- Frequency assignment management (VHF, UHF, SHF).
- Team information.
- One-on-one interference analysis.
- Electronic warfare (EW) threat analysis.
- Subscriber list management.
- Word processing program.
- Spreadsheet program.
- Electronic mail (e-mail) program.
- Packet network monitoring.

The SCC-2 includes the following functional software tools:

- NPE for MSE assets.
- BSM.
- MSE WAN management.
- System administration.
- E-mail.

The ISYSCON program will field the system in a variety of configurations. The ISYSCON(V1) will consist of two servers, four workstations, and ten remotes. The ISYSCON(V1) will reside at the corps signal brigade and the division signal battalions. The ISYSCON(V2) will consist of two servers, two workstations, and five remotes. The ISYSCON(V2) will reside at the corps area signal battalion.

MSRT

MSE network users gain mobile access using the MSRT (AN/VRC-97) through the RAU by affiliating onto the network. MSRTs can receive or send voice, facsimile, or data traffic. The planning range between the MSRT and RAU is 15 kilometers (9.3 miles). Terrain and weather will affect the actual range.

SUBSCRIBER TERMINALS

MSE users initiate and end all communications by using subscriber terminals. The digital nonsecure voice terminal (DNVT), TA-1035-U, provides voice and data access to the MSE network. Its features include:

- Handset.
- Keypad.
- Digital transmission (16 kilobits per second (kbps)).

- Four wire with data port to interface with computer/facsimile (FAX).
- Compatibility with other terminals.

The digital subscriber voice terminal (DSVT), KY-68, provides secure access to MSE for all mobile or fixed subscribers. It functions closely to the DNVT, and its features are the same.

Digital Non-Secure Voice Terminal (DNVT)

The digital nonsecure voice terminal (DNVT) is a ruggedized field telephone. It is operable as a tabletop device in tents, shelters, and office environments. It also may be operated outdoors while strapped to a tree or pole. The DNVT is designed for durability to exposure of the elements during operation and transportation. Voice communication is accomplished through the handset. Digital data from an external device interfaces through the TA-1042A/U's digital data port (DDP). The DNVT transmits and receives full duplex, conditioned diphase digital voice and loop signaling information at 16 or 32 kb/s rates. The DNVT is a nonsecure telephone with no encryption capability. It digitizes voice information using continuously variable slope delta (CVSD) modulation. Digital communication transmissions, both to and from the DNVT, are accomplished using a conditioned diphase (CDP) data transmission method. This is accomplished by using the DDP. The DNVT operates in both common battery mode and local battery point-to-point mode, but not simultaneously.[1] The TA-1035 is another DNVT version. TA-1035 Digital Non-secure Voice Telephone (DNVT) with digital data port is a four-wire telephone set which transmits and receives conditioned diphase-modulated digital data, digitized voice and digital loop signaling at 16 or 32 kbps

Figure D-7. Digital Non-Secure Voice Terminal.

Digital Secure Voice Terminal (DSVT)

The Digital Subscriber Voice Terminal (DSVT) is a TRI-TAC and DGM telephone. The DSVT is comparable to a tactical STU-III and provides digital secure voice over switched or point-to-point communications. In addition, the DSVT has a data port, which, with an appropriate interface, can provide secure data communications. The DSVT can operate in both a secure and nonsecure mode. In the secure mode, the DSVT receives its crypto key from the circuit switch up to the secret level. It should be noted, at levels above secret, the DSVT must be manually keyed by the operator.

This ruggedized terminal can be used for encrypting/decrypting voice traffic and provides secure digitized data traffic. It includes a push to talk handset and operates as a full duplex voice/data subscriber terminal and is switch selectable for 16 or 32 kb/s.

Figure D-8. AN/UXC-7 Fax.

Facsimile

The AN/UXC-7 fax machine was built to military standards in the 1980s by Magnavox and uses a rolling drum to transmit documents. The Army bought 5,000 of them for $105 million, or $21,000 apiece. The UXC-7 is able to transmit data from one location to another over radio, common-user telephone systems, or digital equipment. The UXC-7 connects to the MSE network through the data ports on DSVTs and DNVTs. The UXC-7 can transmit maps, photographs, line drawings, and printed or handwritten messages. While the UXC-7 is still in the army inventory, it has essentially been phased out. The bulky UXC-7 weighs more than 65 pounds in its standard configuration and 110 pounds with supplies. These systems are and were expensive to maintain as well as purchase, more than 500 of the machines are under repair at any given moment. Most machines fail after 2,495 hours of use and cost around $4,325 each in 1998 dollars for repair or overhaul. [2]

User Terminals

The Communications Terminal AN/UGC-144 was an original digital communications terminal with an automated message composing and storage capability to simplify message handling. It was designed for transportability and provides access to the Automatic Digital Network (AUTODIN) and is still found in some MSE units' inventories.

Figure D-9. Communincations Terminal AN UGC 144

The AN/UGC-144's was developed in the 1980s had for the times a user friendly keyboard, display, "stand alone" message terminal for composition, editing, refilling, transmitting, receiving, monitoring, and storing record traffic messages. It has a 40 MB internal hard drive and a removable auxiliary cassette containing at least 512 KB which provides additional capability for easy storage of messages or additional terminal software. The menu-driven software, man-portable characteristics, accessibility, expandability and ease of maintenance allows the AN/UGC-144 to be employed at all echelons of a tactical communications system. The Single Subscriber Terminal (SST) was designed to operate with TRI-TAC/MSE switching equipment at data rates of 75 to 2400 KBS.

MSE RANGE EXTENSION

Figure D-10. Troposcatter Shelter.

The corps signal brigade has a range extension company that allows the grid network to flex with the dynamics of rapidly changing tactical operations. Range-extension packages are organic to this company and deploy according to mission, enemy, terrain, troops, and time available (METT-T) needs. The range extension company has TACSAT Tropo platoons. Range-extension packages have two transmission media forms: TACSAT and light

tropo. Both are vehicular mounted, air transportable, and have multichannel capability. Satellite availability determines the TACSAT range.

The AN/TRC-170 Troposcatter Shelter is a beyond line of sight range –extension package with two antennas mounted on a transportable trailer. It has a range of about 160.9 kilometers (100miles). Prior to OIF, the AN/TRC-170 underwent a system upgrade and with continuing modifications, the TRC-170 capacity has risen from a maximum bandwidth of 4 Mb/sec to 16 Mb/sec once all systems have been upgraded. Operators can now select data rates from 2 to 16 MB/s from the front panel of the modem. The increased capability of the upgraded AN/TRC-170 terminals will be used to reduce the dependence on satellite communications in areas of conflict and to improve the link performance. The TRC-170 is backward-compatible with any non-retrofitted AN/TRC-170, as well as compatible with the AN/TRC-175, (HMDA).

The AN/TSC-85C and AN/TSC-93C are the U.S. Army's two primary tactical satellite terminals. Both satellite terminals use the Defense Satellite Communications System (DSCS) satellites to provide long range connectivity. They typically deploy in a hub-spoke satellite network configuration with the AN/TSC-85C as the hub and the AN/TSC-93C as a spoke.

Figure D-11. Multichanel Satellite Van AN TSC 93

AN/TSC-85 and AN/TSC-93 Ground Mobile Forces Tactical Satellite communications terminals were fielded in the mid-1980s and are used with both MSE and DGM/TRI-TAC based signal units. They were scheduled to be replaced by the Military Satellite Communications Super High Frequency Tri-Band Advanced Range Extension Terminal system known as START-T. Army Transformation initiatives, coupled with the Information Technology revolution, created a dramatic increase in the Army's information throughput requirements at the tactical/expeditionary level. This shortfall is most pronounced in the modular brigade combat teams operating at doctrinal distances that far exceed our current line of site capabilities. This translates to a previously un-resourced beyond line-of-sight (BLOS) capability at brigade, battalion and company echelons that current military BLOS satellite communications capabilities cannot meet. Even though emerging Army and DoD satellite constellations and terminal systems will tremendously increase BLOS capabilities, several programmatic factors will cause this current gap to persist through 2010. [3]

The AN/TSC-93C(V)1 and (V)2 terminals are readily transportable by road, rail, sea, and air (including helicopter lift). The AN/TSC-93 transmits and receives only one X-band carrier and is used as spoke or point to point with one TSSP or two links with the enhanced ETSSP. The electrical equipment shelter S-280 and its associated cables are designed to withstand specific electromagnetic interference and are capable of operating in a hostile chemical, biological, or radiological environment. The equipment design has the capability to isolate faults to the lowest repairable unit. The shelter and antenna are carried on two HMMWVs—each pulling a 10 KW generator—and can be operational in 20 minutes using four technicians or 30 minutes using three technicians.

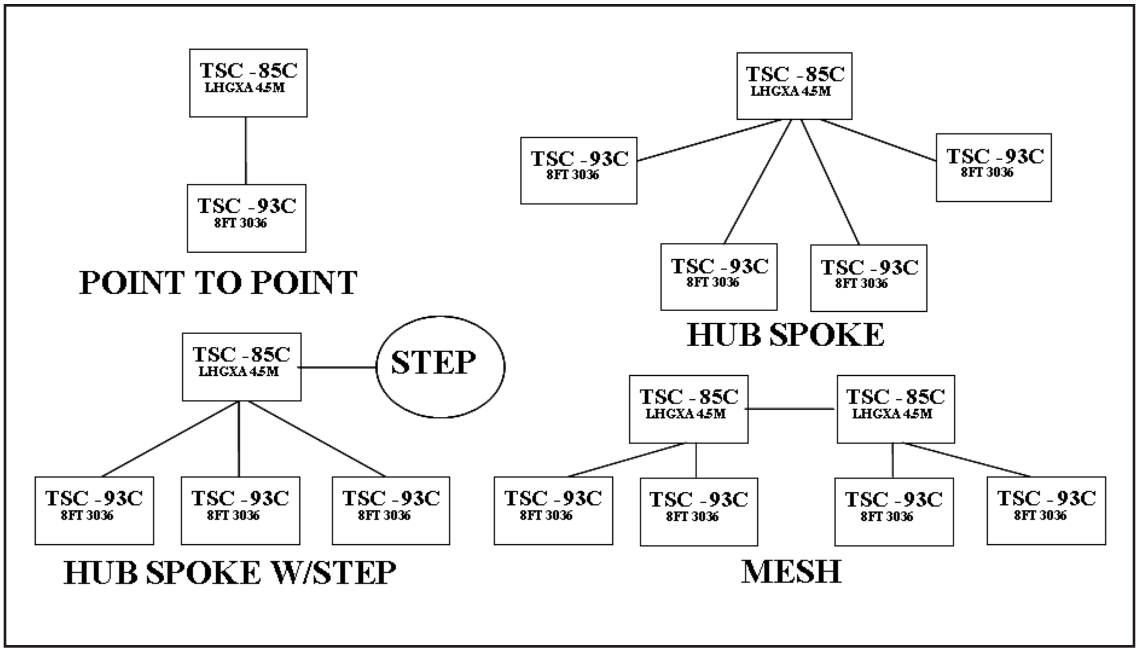


Figure D-12. AN/TSC-93C Configurations.

The AN/TSC-85B/C is similar to the AN/TSC-93. The AN/TSC-85 transmits and receives only one X-band carrier transmits but unlike the TSC93, it can receive up to four X-band carriers with the standard TSSP or five with the enhanced ETSSP. The AN/TSC-85 acts as hub in a hub/spoke configuration. The electrical equipment shelter S-280 is equipped with redundant equipment and its associated cables are designed to withstand specific electromagnetic interference and are capable of operating in a hostile chemical, biological, or radiological environment and are carried on a 5-ton truck. The equipment design has the capability to isolate faults to the lowest repairable unit. The shelter can operate with either the 16' LHGXA or the 20' QRSA antenna. With a full complement of technicians, the set-up time is 30 minutes.

Figure D-13. AN/TSC-85B/C Shelter.

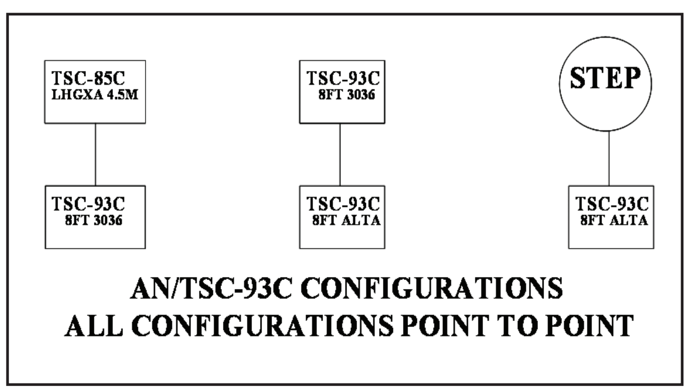


Figure D-14. AN/TSC-85B/C Configurations.

Flyaway Tri-Band Satellite Terminal (FTSAT)

The Flyaway Tri-Band Satellite Terminal (FTSAT) is a commercial off-the-shelf non-developmental item highly transportable tri-band transit case packaged satellite communications terminal capable of supporting a variety of worldwide missions. The FTSAT will interoperate with other GMF terminals such as the AN/TSC-93 and the AN/TSC-85. These terminals were being used in exercises such as Grecian Firebolt '01. FTSAT provides X-, C- and Ku-band satellite communications that support a variety of worldwide missions in both hub and spoke configurations. Setup/teardown time is 30 minutes.

Figure D-15. Flyaway Tri-band Satellite Terminal (FTSAT)

Single Channel Tactical Satellite (SCTACSAT)

The AN/PSC 5 "Spitfire" single channel tactical satellite (SCTACSAT) radio was the single most lauded radio of the war. The SCTACSAT facilitates secure voice and data communications between ground elements that are BLOS, for which it is not possible to support with ground retransmission resources. SCTACSAT has been allocated for use in corps and division warfighter and operations-intelligence nets. SCTACSAT is also utilized for the Early Warning Nets for such items as ballistic missiles. During OIF, COL Ray Palumbo, Commander of the 12th Aviation Brigade stated that "the one system I could count on throughout the fight, the one that never failed me, that kept me connected even as I moved from Kuwait to Tallil to Balad was the Single Channel TACSAT." For the period of this study, V Corps had only three workable wideband 25KHZ channels to fight what had clearly become disconnected formations broadly dispersed across areas that exceeded FM range.[4] V Corps and 3 ID each used their assigned 25KHZ TACSAT channels to establish Corps and Division command nets.

Through the use of the mandated Demand Assigned Multiple Access (DAMA) feature, it will be possible to multi-task a single radio into more than one radio net. This feature reduced the requirement for cascading early warning notification and eliminates the time delays associated with such operational methods.

DGM

Digital Group Mulitplexing (DGM) communications systems are found primarily in EAC Signal Brigades. DGM much like MSE has various integrated components to ensure communication support to its users. DGM systems are comprised of three major groups: switches, LOS radio assemblages, and beyond line of site systems.

DGM Switches

AN/TYC-39A Message Switch

The TYC-39A message switch is similar in size and appearance to the AN/TTC-39D. The TYC-39A is a secure, automatic, processor controlled, store-and-forward message switching facility that operates in networks consisting of either dedicated or circuit-switched subscriber terminals. Prior to being phased out by the advent of the SSS, the TYC-39A interfaced with and provides tactical AUTODIN services. The TYC-39A message switch was found at Corps, EAC and Joint levels.

AN/TTC-39D

The AN/TTC-39D began its service to the Army Signal Corps in 1984 and has been phased out by the smaller more modular AN/TTC-56 Single Shelter Switch. The 39D was still in the Army inventory at the time of OIF-1. It is a modular and transportable mobile subscriber access circuit switch designed to provide secure and nonsecure automatic switching and technical control for analog, digital, and mobile subscriber traffic. The AN/TTC-39D was the first all digital circuit switch with the capacity to terminate 712 lines (both analog and digital). The AN/TTC-39D also has flood search capability and is fully compatible with fielded Mobile Subscriber Equipment. When designed, it had control functions including channel reassignment, multiplexing, line testing, and engineering orderwire. The system also ran technical control functions for atomic timing standards, analysis of trouble reports, alarms, and system data.

AN/TTC-56 Single Shelter Switch (SSS)

The AN/TTC-56 like the 39D is capable of interfacing with both EAC and MSE systems. While the 39D was able to support more links, residing on a 5-Ton vehicle, it was much larger and more difficult to transport a difficult than the smaller SSS. The AN/TTC-56 SSS is a downsized, mobile, and transportable tactical digital circuit switch that includes a packet switch and a packet gateway fielded to EAC signal units. The AN/TTC-56 interfaces with DSN, NATO, commercial and tactical telephone switches, switchboards, and various subscribers' telephones.

AN/TYC-39A Message Switch

- Central routing mechanism for:
  - teletypewriter
  - low-speed data information
- Accepts group of characters called messages
- Reads the message's routing information
- Stores message in computer memory
- When a circuit becomes available:
  - forwards to destination or
  - another message switch closes to the destination

- Circuit Switches - one at a time
  - NCS, LEN, TTC-39A/D
- AUTODIN Switching Center (ASC)
- With Dedicated Subscriber Terminals
- Dedicated Message Terminals
  - 1.2 - 32 K
  - KG-84 & terminal
- Dial - up Circuits
  - Through CS network
  - Loop rate of network
  - KY-68 & terminal

Figure D-16. AN/TYC-39A Message Switch.

The AN/TTC-56 SSS is an improved tactical circuit switch began replacing the AN/TTC-39D circuit switch as early as 1999. It is housed in a lightweight, multipurpose shelter and mounted on an M1113 expanded capacity vehicle. The SSS provides voice and packet switching capability using small, lightweight, and modular switching equipment. It tows a trailer-mounted diesel engine generator set that provides 10-KW primary operating power for the system.

Multiconductor and coaxial cable connections made at the signal entry panel accommodate signal traffic in and out of the SSS. Connector receptacles on these panels carry the signals through the shelter wall. Inside each signal entry panel, electrical surge arrestors and high voltage assemblies on the individual signal lines protect electrical equipment from transient high voltage pulses. All panel connector receptacles are waterproof. A hinged cover extends over the panel to provide additional protection against the environment. A grounding stud is located on each signal entry panel.

The following are subscriber features possible with the SSS:

- Subscriber profiles.
- Multilevel precedence and preemption.
- Precedence level dialing.
- Conference calling.
- Call security.
- Call forwarding.

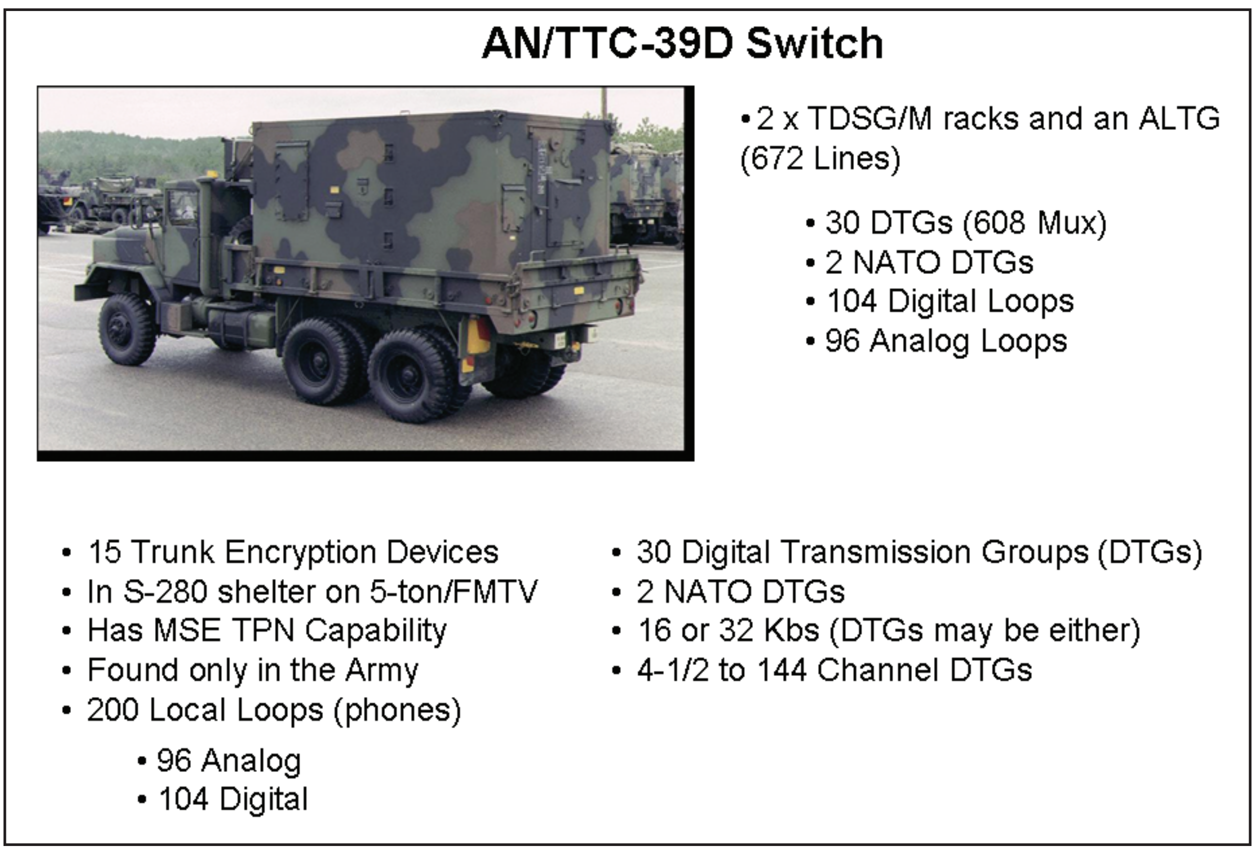


Figure D-17. AN/TTC-39D Message Switch.

Figure D-18. Single Shelter Switch AN TTC 56

- Zone restriction.
- Commercial network access.
- Compressed dialing.
- Direct dialing.[5]

DGM Radio Van Assemblages

High Mobility Digital Group Multiplexer (DGM) Assemblage (HMDA)

The HMDA provides 25 miles LOS transmission and 12 miles fiber optic cable range. The HMDA radio vans utilize the Deployable Antenna Mast Positioning System or DAMPS antenna. This antenna system can reach any designated height from 3-30 meters based on mission and terrain. The HMDA is used only at Echelons Above Corps. There are four types of HMDA:

1. AN/TRC-138C: This is also a LOS Radio Repeater Assemblage that provides the ability to extend the range of the -175B. The AN/TRC-138:
   - Terminates up to two 144 channel systems and one 576 channel SRWBR link at Top-of-the-hill node;
   - SRWBR transmission range of 5 miles;
   - LOS internodal transmission range of 25 miles.
2. AN/TRC-173B: This is a LOS Radio Terminal Assemblage that connects to various EAC Switching Assemblages and also provides access to local subscribers via equipment supplied by the Unit. The AN/TRC-173 has:
   - Two systems per assemblage;
   - Terminates 8 to 36 channels each;

- Provides access to subscribers via RMC or RLGM;
- Multiplexes loop groups and transmits to the 174.

3. AN/TRC-174B: This is a LOS Radio Repeater Assemblage that provides the ability to extend the range of the -173B. The AN/TRC-174 has:
   - Three systems per assemblage;
   - Provides ability to extend range of 173;
   - Interfaces with 138A/B/C, 173, and other 174s.

4. AN/TRC-175B: This is also a Radio Terminal Assemblage that connects to various EAC Switching Assemblages, but it uses a different LOS radio than the -173B and provides a greater channel capacity. The newer TRC-175C includes a Troposcatter radio transmission capability in addition to a newer LOS radio, which provides range extension. The AN/TRC-175:
   - Terminates two 576 channel systems;
   - Provides SR WBR facility for Bottom-of-the-hill node;
   - SRWBR transmission range of 5 miles.

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Appendix E
Technical System Links

The links below will take the reader to web sites that describe the systems.

ABCS	http://www.defensedaily.com/progprof/army/abcs.pdf http://www.fas.org/man/dod-101/sys/land/abcs.htm
ADOCS	http://www.gdc4s.com/Products/adocs.htm
AFATDS	http://www.fas.org/man/dod-101/sys/land/afatds.htm http://www.raytheon.com/products/afatds/
AMDWS	http://bctc.hood.army.mil/wbt/fbcb2/00_glossary/amdws.htm http://www.defensedaily.com/progprof/army/amdpcs.pdf
C2PC	http://home.inri.com/products/c2pc.html http://www.globalsecurity.org/intell/library/reports/2001/compendium/c2pc.htm
DTRACS	http://www.titan.com/products-services/load_pdf.html?filename=86__1053001002.pdf
EPLRS	http://www.gordon.army.mil/tsmtr/eplrs.htm http://www.raytheon.com/products/eplrs/ http://www.fas.org/man/dod-101/sys/land/eplrs.htm http://www.raytheon.com/products/eplrs/
FBCB2	http://peoc3t.monmouth.army.mil/FBCB2/fbcb2.html
GCCS	http://www.fas.org/nuke/guide/usa/c3i/gccs.htm

Hunter UAV	http://www.army-technology.com/projects/hunter/
JDLM	http://www.tapestrysolutions.com/index.php?Option=JDLM http://www.amso.army.mil/BCSEtopics/sim-sys/joint/jdlm.htm http://www.21tsc.army.mil/SimCenter/jdlm.html
LRASSS	http://www.raytheon.com/products/lras3/ http://www.sec.army.mil/aiew/Branches/Sensors/systems/lras3/lras3.htm
MCS	http://www.fas.org/man/dod-101/sys/land/mcs.htm
MSE	http://www.fas.org/man/dod-101/sys/land/mse.htm
MTS	http://www.comtechmobile.com/cmdc/MTS.html
SINCGARS	http://webhome.idirect.com/~jproc/crypto/sincgars.html http://www.fas.org/man/dod-101/sys/land/sincgars.htm
TAIS	http://www.gdds.com/tais/main.html
TACSAT	http://www.monmouth.army.mil/peoc3s/trcs/MF1SPITF.htm
TBMCS	http://jitc.fhu.disa.mil/gccsiop/interfaces/tbmcs.htm http://www.fas.org/man/dod-101/sys/ac/equip/tbmcs.htm
TeleEngineer	http://asc.army.mil/docs/pubs/alt/current/issue/articles/22_TeleEngineering_200501.pdf

Appendix F
GBS Data Sources

Information Type	Source Provider	Application	Mode to Control Station	Format	Classification
Tomahawk MDU	CMSA, PEO CU, Tiburon		SIPRNET/TCP/ IP/NES	Binary	SECRET
Weather	ACC/AFGWC		SIPRNET/TCP/IP	Binary	SECRET
	NWS		SIPRNET/TCP/IP	ASCII	Unclassified
	SPAWAR/Navy METOC		MILNET	IF	Unclassified
Tactical EOB	JAC	JICPAC	SIPRNET/TCP/IP	ASCII	SECRET/TS SCI
Maps	DMA	PowerScene	SIPRNET/TCP/IP	Binary	SECRET
Imagery	OSO/National Sources	IMACTS	SIPRNET/TCP/IP	NITF 2.0	SECRET
	OSO/IMACTS	IMACTS	LES ATM Net	NITF 2.0	SECRET
Television (MWR Programming)	AFRTS		Commercial Satellite	TVRO	Unclassified
	CNN		Commercial Cable	Video	Unclassified
BINOCULAR	NSA/DIA	BINOCULAR	BINOCULAR Broadcast	Constant Source	SECRET
TIBS	AIA		TIBS Broadcast		SECRET
TRAP	OSO/National Sources		TRAP Broadcast		SECRET
Consistent Operational Picture	CJTF/SPAWAR		SIPRNET/TCP/IP	OTH-G	SECRET
ATO	In Theater (JAC)	JDISS/JMCIS	SIPRNET/TCP/IP	ASCII	SECRET
JSTARS Data	CECOM/CGS		TCP/IP	Binary	SECRET
Intel Briefings	JICPAC		DCTN	Digital Video	Unclassified
Medical Video	CHSS/DSCS		DSCS	Digital Video	Unclassified
Imagery	CIO	IMACTS/IPL	DISN LES/disk/ tape	Binary	SECRET
Imagery Other Govt.	LANDSAT	LANDSAT	Disk	Binary	SECRET
	SPOT	SPOT	Disk	Binary	SECRET
Imagery Allied	French, UK	LOCE	WAN	Binary	SECRET/NATO
Target Nominations	SAIP Data Dissemination	Messages	Commercial SATCOM	ASCII	SECRET/TS
Terrain Data	TEC	Various	Optical Disk	Binary	Unclassified/ SECRET
Missile Warning	Space Command				
Databases	GCCS	JDISS	DISN	Various	TOP SECRET
	ASAS	JDISS	DISN	ASCII	SECRET/TS/SCI
	NTM	JDISS	DISN	Binary	SECRET/TS

Information Type	Source Provider	Application	Mode to Control Station	Format	Classification
	LOCE	JDISS	DISN	ASCII	SECRET NATO
Record Messages	DoD	JDISS	DISN	ASCII	SECRET
Education	TRADOC	Video	Video		Unclassified
Training	TRACDOC	Video	Video		Unclassified
News	Wire Services/ Government	Wire Service	DISN		Unclassified
Logistics Files	National & Theater Maintenance Points		MILNET		SECRET
Keymat	NSA				SECRET/TS
Situation Awareness	ASAS, ADSI	Various	Various/TIBS/ TRAP/Trojan Spirit	Text	SECRET
Law Enforcement	FBI, JAG, MP	Internet	Internet	ASCII	Unclassified
UAV Video	MAE (Predator)	Video	DBS		SECRET
U2R Imagery	CARS	NITF 2.0		Senior/Span/ CDL	SECRET
	Senior Span	NITF 2.0		Senior/Span/ CDL	SECRET
	Senior Blade	NITF 2.0		Senior/Span/ CDL	SECRET
SIGINT	Guardrail/ES3/ EP3/ Rivet Joint	Various	TIBS/TRAP Broadcast		SECRET
SEAD	Rivet Joint/NTM/ Guardrail/EA-6B	JTIDS	JTIDS	JTIDS	SECRET
Ground Picture	JSTARS	Video/Frame		CGS	SECRET
Air Picture	AWACS/EA6B/E-2C	JTIDS/Link 11/ Link4	JTIDS/Link 11/ Link4	JTIDS	SECRET
Target Updates	AWACS/JSTARS/ CARS/DOCC		Tactical Nets		SECRET
Gun Camera	Avn BDE/WOC/ CAG	NTSC Video	VCR Tapes	VCR Tapes	SECRET
Intel Briefings	JTF HQ/ASAS/ TACC/LOCE	Text	Tactical Nets	ASCII	SECRET
SITREPS	JTF/ASAS/DIV/ BDE/LOCE	Message	Tactical Nets	ASCII	SECRET
MISREP/ BDAREP/ MJIREP	WOC/CAG	Text	Tactical Nets	ASCII	SECRET
Op Orders	U.S. & NATO HQs	Text	Tactical Nets	ASCII	SECRET
ATO/ACO/SPINS	JFACC		Disk/Paper		SECRET
Manuals			Optical Disk	ASCII	Unclassified
Software	JTF		Disk	Binary	Unclassified
VTC	Corps/Division/ Brigade	COMPASS	Tactical Nets	Digital Video	SECRET
Battlefield Awareness	ASAS/ADSI/ JMCIS/ LOCE	Various	Tactical Nets		SECRET

Information Type	Source Provider	Application	Mode to Control Station	Format	Classification
Exploitation/ Fusion	ASAS/GCSI/CIS/ JMCIS/LOCE	Various	DISN/Tactical Nets	ASCII Text	SECRET
MTI (if not part of EGSM)	Bde EGSM	EGSM	Tactical Nets	Text	SECRET
Mission Rehearsal/ flythrough	TOPSCENE	TOPSCENE		Digital Video	SECRET
Air Tasking Orders	CTAPS				SECRET
Misc. Text, Internet/CDs/ tapes, etc.	Various	Various		Text	SECRET
Mission Rehearsal/ Flythrough	AMRS/ COMPASS	AMRS/ COMPASS		Digital Video	SECRET

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